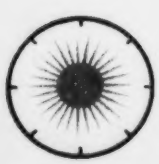

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PROTOTYPING AND TESTING THE RETROFIT OF RESIDENTIAL GAS FIRED FURNACES WITH INDUCED DRAFT FANS AND INTERMITTENT SPARK IGNITION

Final Report

By

The Conserver Group Inc.

63pp

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PROTOTYPING AND TESTING THE RETROFIT OF RESIDENTIAL GAS FIRED FURNACES WITH INDUCED DRAFT FANS AND INTERMITTENT SPARK IGNITION

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SUMMARY

The primary purpose of this study was to establish the technical feasibility of retrofitting conventional gas fired furnaces with intermittent spark ignition and induced draft fans in the field. The secondary purpose of the study was to determine the effect of the retrofit on the steady state and seasonal efficiencies of the furnaces, and to perform a cost/benefit analysis.

Two used gas furnaces and one used gas conversion oil furnace were tested in a laboratory as conventional units, retrofitted by a local contracting firm as per engineered specifications, and then retested in the laboratory to determine the effects of the changes. The tests performed in both cases included temperature measurements, pressure (draft) measurements, and flue gas analyses. In addition, the effectiveness and/or requirement for furnace safety controls was tested.

Representative tests for each furnace, before and after retrofit, indicated that steady state efficiency improvements of 2.2%, 14.6% and 9.9% were obtained for the three furnaces tested. In addition, seasonal efficiency improvements of 18.2%, 30.6% and 25.6% were estimated.

Based on the above estimated seasonal efficiency improvements, a total retrofit cost of $700 and an average annual heating cost of $619 per year in Winnipeg (120 MCF of gas), the simple payback period of this retrofit is 4.0 years.

Therefore, it was concluded that it is technically feasible, as well as cost effective, to retrofit a conventional gas fired furnace with an intermittent spark ignition and an induced draft fan in the field.

SOMMAIRE

Le but premier de cette étude était d'établir la faisabilité technique de modifier, à l'extérieur du laboratoire, une fournaise conventionnelle au gaz avec un allumage à étincelle(bougie) intermittent et un ventillateur installé à l'entrée de la cheminée. Le second but de cette étude était de déterminer l'effet de ces modifications sur l'état stationnaire et sur l'efficacité saisonnière des fournaises et également d'établir une analyse coût/bénéfices.

Deux fournaises à gaz usagées et une fournaise à huile usagées ont été testé comme unité de référence, les modifications ont été effectué par un contracteur local qui a suivi les spécifications d'ingénieur, et alors les fournaises ont été retesté en laboratoire pour déterminer l'effet des changements apportés. Les tests effectués dans les deux cas incluaient des mesures de températures, de pressions et d'analyse des gaz de combustion. En plus, l'efficacité et/ou l'exigence d'un contrôle sécuritaire de la fournaise était testée.

Les test représentatifs pour chaque fournaise, avant et après les changements, indiquaient que l'efficacité de l'état stationnaire avait augmentée de 2.2%, 14.6% et 9.9% pour les trois fournaises testées. De plus, une amélioration de l'efficacité saisonnière de 18.2%, 30.6% et 25.6% a été estimer.

En se basant sur l'estimation de l'augmentation de l'efficacité saisonnière, le coût total des modifications est de 700$ et sur la moyenne annuelle du coût de chauffage qui est de 619$ par année à Winnipeg(120 mpc de gaz), la période de recouvrement de l'investissement est de 4.0 ans.

Donc, il a été conclut qu'il est techniquement faisable, à un cout raisonnable, de modifier une fournaise à gaz conventionnelle avec un allumeur à étincelle intermittent et avec un ventillateur inducteur.

1.0 INTRODUCTION

The primary purpose of the work performed under this contract was to establish the technical feasibility of retrofitting conventional* gas fired furnaces with intermittent spark ignition and induced draft fans in the field (i.e. not in a furnace manufacturer's factory). The secondary purpose was to determine the effect of the retrofit on the steady state and seasonal efficiencies of the furnaces, and to perform a cost/benefit analysis.

This was accomplished by:

1) Setting up three standard gas furnaces complete with chimneys, breeching supply air plenums, etc. in accordance with applicable codes, as would be found in a typical residential situation, and testing them to establish baseline performance.

2) Designing and performing the retrofit of the three furnaces by installing spark ignition systems and induced draft fans and then reconnecting the three furnaces to the same chimneys and retesting them to determine both safety of operation and changes in performance (steady state efficiency).

3) Determining labour and material costs from discussions with equipment suppliers and Furnasman Ltd. ICG Utilities (Greater Winnipeg Gas Co) advised of the average annual heating cost in Winnipeg in order that the simple payback period could be calculated.

*A "conventional" gas fired furnace is a forced air furnace equipped with a draft hood and a continuous pilot It can be either a furnace intended for gas firing, or a converted oil furnace.

2.0 BACKGROUND

2.1 FURNACE DESIGN AND SEASONAL EFFICIENCY

In the past, the low cost of energy and traditional economic practices within the construction industry (i.e. low bid) have resulted in the installation of relatively inexpensive conventional gas furnaces, often with a highly rated (80%) operating (steady state) efficiency. However, inherent in their designs are factors that lower their seasonal ef ficiency:

- In cold weather, when the furnace is off, lighter warm air from the home enters around the burners or into the draft hood and rises up the chimney. This air is replaced by heavier cold outside air infiltrating into the house, which, of course, has to be heated. When the furnace is on, air that is excess of the required combustion air is sucked into the combustion chamber, and even more air is usually sucked into the draft hood to rise out of the chimney.

- In addition, the excess air sucked into the combustion chamber both increases the volume and reduces the temperature of the combustion gases. This increased volume increases the velocity of the hot gases over the heat exchanger, and this, combined with the lower temperature of the combustion gases, reduces the amount of heat transferred through the heat exchanger. These factors contribute to reduce the average seasonal efficiency of conventional residential hot air furnaces to 55-60%.

Rising energy costs have recently resulted in "mid-efficiency" and "high efficiency" furnaces coming onto the market. However, the replacement of existing furnaces is relatively expensive with long payback periods. Therefore, most homeowners are instead choosing to continue to use their existing furnaces, and as a result, wasting vast amounts of energy and money, particularly when viewed on a national basis.

Because of generally rising energy costs and government sponsored public awareness programs on energy conservation, people are seeking ways of reducing energy costs. The market potential of such a desire has been recognized: Various promoters and manufacturers, some well-meaning but misguided, others seeking to exploit public ignorance, are

responding with a wide range of products, often accompanied by exaggerated claims of potential savings. Worse, some are unsafe.

On the other hand, some legitimate methods of reducing energy costs through retrofit of existing furnaces have been researched, and based on some field studies, including the U.S. gas industry initiated "Space Heating Efficiency Improvement Program" (SHEIP), generalized savings have been predicted. Some of these are summarized in a paper for the BECS Seminar on Efficient Residential Heating systems issued by the Canadian Combustion Research Laboratories (CCRL).

The availability of a proper method of retrofitting furnaces, in combination with a public education program, should prevent consumer abuse and safety problems related to furnaces. This would avoid a repetition of the abuses and excesses that accompanied much of the upgrading of insulation levels in homes. From the various options, it is felt that the combination of an induced draft (ID) fan and intermittent electronic ignition would provide the best payback.

If an ID fan were installed, then the combination air/gas mixture would be more precisely controlled, thus raising the temperature and reducing the volume of the combustion gases, thereby increasing the amount of heat transferred into the home. In addition, the draft hood, which would no longer be required, would be removed, thus eliminating both operating and standby air losses through this dilution device.

The removal of the draft hood would require replacing the constant pilot valve assembly with an electronic ignition system. An intermittent electronic ignition system has the added benefit of eliminating constant pilot losses by starting the pilot gas flow and igniting the pilot electronically only when the thermostat in the home calls for heat. (For safety reasons, the main gas valve can open only if the operation of the pilot and the ID fan is proven, and will close if either the flame goes out or the fan stops.)

The retrofit of existing furnaces with an ID fan and intermittent electronic ignition would, according to Mr. A.C.S. Hayden of CCRL, create seasonal efficiencies of the order of 80%, and thus yield fuel savings of from 10% to 30%, depending on the furnace design, with most savings closer to 30%.

Some furnace manufacturers must also agree that this is a good combination, because some of the most recent entries into the intermediate efficiency range, such as the Lennox Conservator III, the Clare Command-Aire, and the Airco 8300 TURBO, feature a standard gas-fired furnace equipped with an induced draft fan and electronic ignition.

However, at this time, little or no retrofit of existing household gas-fired hot air furnaces is permitted in Canada, as explained below.

2.2 RESTRICTIONS ON MODIFYING RESIDENTIAL FURNACES

In Manitoba, the provincial Dept. of Labour is the code authority for gas-fired appliances, and the gas utilities have been given the authority to be inspection agencies, that is, they have been made responsible not to supply gas to an appliance unless it is "approved" by the Canadian Gas Association (CGA), and the installation meets code requirements. (Similar controls exist in other jurisdictions.)

However, any modification of an approved gas-fired appliance voids the approval certificate. Therefore, modification can only be performed with the permission of the code authority, and the changes must be inspected and approved prior to the re-lighting of the appliance.

In most jurisdictions, the code authorities have generally taken the position of not approving additions or alterations to gas-fired household furnaces rather than risk situations where danger to health or safety could result. One notable exception is bi-metallic flue dampers which are now permitted to be attached to the furnace chimneys in some provinces.

Since no furnace retrofit is permitted, there is little or no experience with field retrofit, except for individuals who do so without notifying the code authorities.

This study is intended to create some experience in field retrofitting of residential furnaces, and is based on the methods of those furnace manufacturers who have created their mid-efficiency furnaces essentially by fitting their standard residential models with induced draft fans and intermittent electronic ignition.

3.0 METHODOLOGY (Chronological Description of Work Performed)

3.1 PRE-RETROFIT

Two used gas furnaces and one used oil furnace were obtained. The oil furnace was converted for operation with natural gas by installation of an upshot gas burner. Following are the makes and models of the three furnaces:

GF#1 Clare Model MBG200 natural gas furnace
Rated Input 200 000 Btuh

GF#2 Furnasman Model HG90-2W natural gas furnace
Rated Input 90 000 Btuh

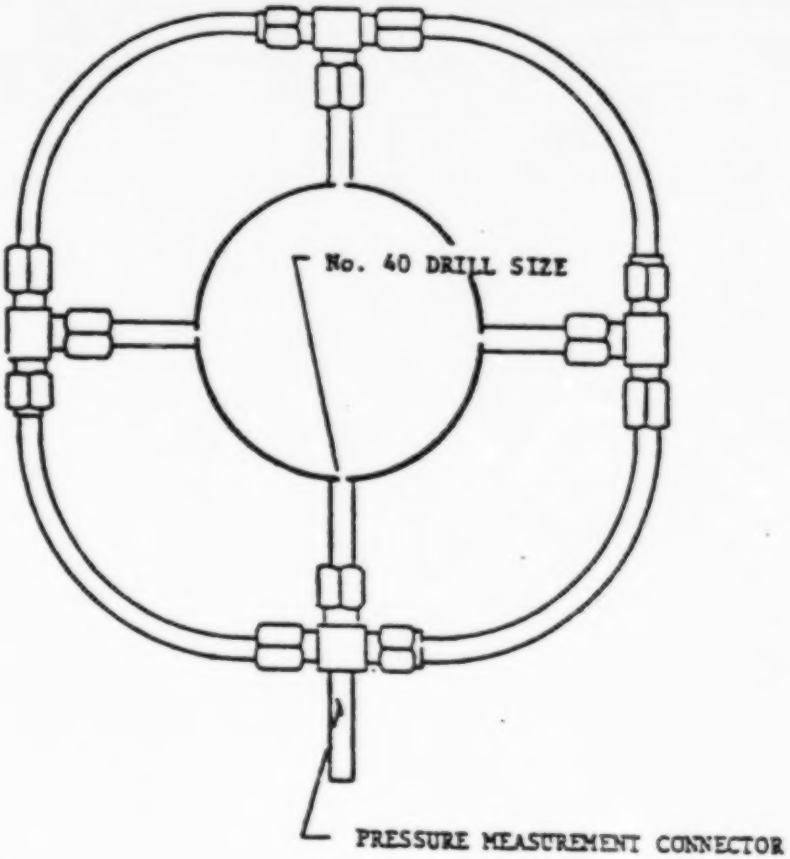
GF#3 Bulloch Centurion Series oil furnace,
Model No. AC-123-0
Rated Output
c/w Barber-Aero Model UPB190 upshot gas burner and three different nozzle sizes: No. 4, No. 15 and No. 26

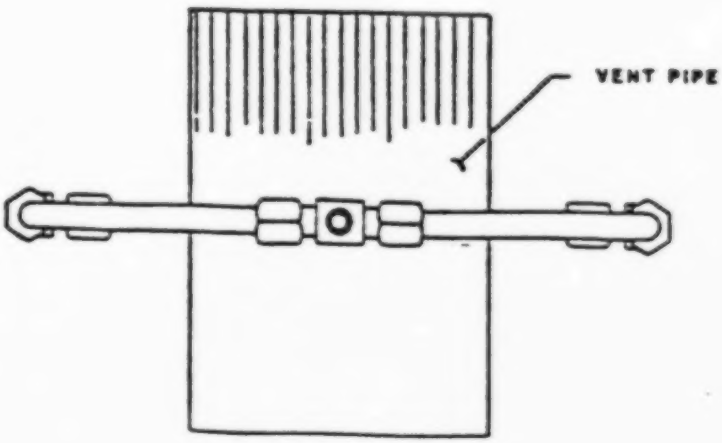
These conventional furnaces were set up at the laboratory facilities at the Industrial Technology Centre (ITC) according to normal trade practice. The Manitoba Department of Labour inspected the installations and found them to be in conformance with all applicable codes.

The Furnasman and Bulloch furnaces (GF#2 and GF#3) were connected via separate 5"Ø single wall vent connectors into a common 5"Ø Type B Gas Vent (chimney). These furnaces were operated alternately, and the breeching from the idle furnace was physically blocked via a blast gate so as not to affect the test results. The Clare furnace (GF#1) was connected via a 7"Ø single wall vent connector into its own 7"Ø Type B Vent (chimney).

Pressure tap collars were installed in the single wall vent connectors of each furnace for the purpose of measuring chimney draft. The pressure tap collars were constructed as shown in Figure 1.

The three unmodified furnaces were tested at steady state conditions by ITC using the National Standard CAN1-2.3-M84 "Gas Fired Gravity and Forced Air Central Furnaces" as a guide. The results as tabulated by I.T.C. for all testing (pre-retrofit and post-retrofit) are provided in Appendix 1.





	REVISIONS	DATE	APP.
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SHEET ____ OF ____	DWG. No. ____	Figure 1	

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Pressure Tap Collar

Several temperature and draft (pressure) measurements as well as flue gas analyses were performed on each furnace. The locations at which measurements were taken are shown in the sketches of the furnace vent arrangements given in Appendix 2.

3.2 RETROFIT DESIGN

The retrofit design was conceived by The Conserver Group Inc. in conjunction with Furnasman Ltd. following which design specifications were prepared (Appendix 3). Furnasman Ltd. retrofitted the Bulloch (GF#3) and Furnasman (GF#2) furnaces as per specifications. However, the Clare (GF#1) furnace was retrofitted with a reconditioned Torin induced draft fan (originally from a high efficiency condensing furnace) which necessitated a different mounting configuration than originally planned. Photographs of the three furnaces and the test set-ups, both before and after retrofit, are included in Appendix 4.

The design was intended for easy field installation and includes the following features:

- Construction of a flue header on the outlets from the heat exchangers using the furnaces existing sheet metal draft hood enclosures.

- A flue transition box on the discharge side of the induced draft (I.D.) fan, which incorporates fan proving sensors and interchangeable orifice plates for adjusting I.D. fan volumes.

- Honeywell intermittent control modules (Models S86E and S86G) and combination gas valves (Model VR8440P).

The furnace controls were set up to provide the following sequence of operation:

1) Space thermostat calls for heat (i.e. its contacts close).

2) Induced draft (I.D.) fan starts.

3) Pressure (fan proving) switch contacts close. (If pressure switch does not prove, sequence stops.)

4) Spark generator is energized, the pilot valve operator opens and the pilot burner lights.

5) Pilot sensor is satisfied by pilot burner heat.

6) Main gas valve opens and spark generator is de-energized.

7) Main burner flame ignites.

8) When the hot air supply temperature reaches its setpoint, the blower thermostat starts the blower.

9) Furnace operation continues as long as the following conditions are met:

   i) space thermostat continues to call for heat;
   ii) burner remains lit;
   iii) air proving switch detects sufficient air flow;
   iv) temperature at high limit control remains below its 200°F setpoint.

10) When the space thermostat is satisfied, the main gas valve and pilot valve are shut and the I.D. fan is shut off.

11) The supply blower continues to operate until the supply air temperature drops to the setpoint of the blower thermostat (normally 120°F on, 90°F off).

A representative of the Manitoba Department of Labour inspected the retrofitted furnaces and was given a copy of the design specifications. He advised that there is an interim requirement that all new furnaces be equipped with a manual reset button to restart the furnace once the vent safety shut off system has been activated. Upon further investigation, this requirement was found to be a proposed amendment to the National Standard CAN1-2.3-M84 which becomes effective in February, 1987. The amendment requires that furnaces without draft hoods intended for connection to a natural draft venting system must pass the following test after operating for at least 15 minutes:

> "A restriction shall be imposed at the vent outlet to result in a pressure of (+ ive) 0.05 inches w.c. as measured by the piezo ring shown in Figure (1). The furnace shall then be shut off, allowed to cool, and then restarted.

> With the restriction in place, the vent safety shut off system shall act within 5 minutes to shut off the gas to the main burner(s) and the venting blower and/or burner blower, when the furnace has been put into operation from cold-start conditions. After the vent safety shut off system has shut off the main gas supply, the furnace shall be immediately thereafter re-started, and the safety shut off system shall act within 1 minute to shut off the main gas supply and the venting blower and/or the burner blower. In each case, a manual reset of the safety shut off system shall be required to re-start the furnace."

The manufacturers have responded to this requirement by providing an add-on "vent limit kit" which is essentially a high limit thermostat located at the flue collar of the furnace which shuts off power to the furnace if the flue gas temperature exceeds its setpoint (factory set). This switch then requires a manual reset before the furnace can be re-started.

Since we were unaware of this requirement at the time the retrofits were designed, and since it would not affect the technical feasibility of the retrofit, the three furnaces were not equipped with "vent limit kits". As we investigated this item, we talked to several people from the Manitoba Department of Labour, CGA, Greater Winnipeg Gas Co., and field servicemen and have uncovered both confusion and varying opinions concerning the necessity and/or effectiveness of this feature. We were further advised that this requirement may yet be rescinded. In any event, this feature could easily be incorporated into our retrofit design at an additional cost of approximately $35.

3.3 POST-RETROFIT

The three retrofitted furnaces were reconnected to the same B-Vent chimneys and supply air plenums as for the pre-retrofit tests. The three furnaces were tested at steady state conditions (again using National Standard CAN1-2.3-M84 as a guide) with different sizes of orifice plate restrictors in the flue transition box at the I.D. fan discharge. The results of these post retrofit tests, as prepared by ITC are given in Appendix 1. The general procedure was to test each furnace initially with a large diameter orifice plate and gradually reduce the orifice diameter (flue gas flow rate) until the maximum operating

efficiency was obtained (i.e. carbon monoxide levels in the flue gases approached the maximum acceptable level of 0.04%). Some tests were repeated with the I.D. fans operated at a reduced voltage of 102 V (at lower voltages, the I.D. fan volume output is reduced) to ensure that the CO levels of the flue gases were within acceptable levels.

The induced draft fan proving differential pressure switch on each furnace was adjusted for each orifice plate size so that the pilot and main gas valves would close when the chimney outlet was physically blocked and when power to the induced draft fan was cut-off.

Wind tests were omitted since according to CAN1-2.3-M84 they are applicable only to direct vent central furnaces (i.e. furnaces with combustion air supplied directly from outside).

Calculated Test Results

Test Condition	Air/Fuel Ratio	Actual Flue[2] Volume (m^3/hr)	Excess[3] Air (%)	Flue Gas Temp. (^oC)[1]	Dewpoint ^oC (^oF)	Steady State Furnace Efficiency (%)	CO (%)
Furnace: Clare							
Pre-Retrofit							
1. Open draft hood	22.8	103.5	160	159	43 (109)	77.3	0.04
2. Blocked draft hood	23.4	106.2	169	225	42 (108)	71.1	0.03
Post-Retrofit							
3. 50.8 mm (2") orifice	21.4	89.5	124	223	44 (111)	74.1	0.006
4. 44.4 mm (1.75") orifice	16.4	68.8	73	240	49 (120)	76.4	0.008
5. 38.1 mm (1.5") orifice	16.1	67.3	70	220	49 (120)	78.0	0.01
6. 38.1 mm orifice (A) 120 V	14.3	60.1	51	220	51 (124)	79.5	0.007
(B) 102 V	13.8	58.0	46	216	52 (126)	80.2	0.02
Furnace: Furnasman							
Pre-Retrofit							
7. Open draft hood	25.0	59.3	163	254	43 (109)	69.6	<0.01
8. Blocked draft hood	20.2	47.9	113	308	45 (113)	68.9	<0.01
Post-Retrofit							
9. 38.1 mm (1.5") orifice (A) 120 V	27.6	62.7	190	250	39 (103)	67.7	0.01
(B) 102 V	26.1	59.3	175	241	40 (104)	69.6	0.01
10. 31.7 mm (1.25") orifice (A) 120 V	15.3	34.7	61	198	50 (122)	80.2	0.007
(B) 102 V	15.4	34.9	61	188	50 (122)	80.8	0.007
11. 25.4 mm (1.00") orifice (A) 120 V	12.7	28.7	33	148	54 (129)	84.2	0.02
(B) 102 V	12.6	28.5	32	150	54 (129)	84.1	0.03
12. 25.4 mm orifice, Bypass Limit Control	12.4	28.2	31	156	54 (129)	83.9	0.05

Cont'd

Table 1

Calculated Test Results

Test Condition	Air/Fuel Ratio	Actual Flue[2] Volume (m^3/hr)	Excess[3] Air (%)	Flue Gas Temp. (^oC)[1]	Dewpoint ^oC (^oF)	Steady State Furnace Efficiency (%)	CO (%)
Furnace: Centurion (oil to gas conversion)							
Pre-Retrofit							
13. Open draft hood, firing rate: 3.48 m^3/h	10.8	37.5	14	329	57 (134)	77.4	0.03
14. (A) Open draft hood, firing rate: 1.8 m^3/h	17.7	31.8	87	284	48 (118)	73.2	<0.01
(B) Open draft hood, firing rate: 1.8 m^3/h, tested after the draft hood	30.5	54.9	220	279	37 (99)	62.9	<0.01
Post-Retrofit							
15. 38.1 mm (1.5") orifice (A) 120 V	12.6	33.1	32	290	54 (129)	78.1	0.008
firing rate: 2.64 m^3/h (B) 102 V	12.2	32.2	29	289	54 (130)	76.0	0.01
16. 31.7 mm (1.25") orifice (A) 120 V	14.0	26.1	52	198	52 (126)	81.3	0.008
firing rate: 1.86 m^3/h (B) 102 V	13.9	25.9	50	203	52 (126)	81.1	0.008
17. 28.6 mm (1.125") orifice (A) 120 V	12.5	25.3	36	180	54 (129)	83.1	0.01
firing rate: 1.86 m^3/h (B) 102 V	12.1	22.5	31	183	54 (130)	83.1	0.04

Notes:

1. Measured at the flue collar.
2. At actual conditions.
3. For tests 1, 7, and 14B, includes dilution air through the draft hood.

Table 1 - Cont'd

Table 2

Summary of Test Results

Furnace Test	Orifice Size (mm)	Steady State Efficiency (%)	Seasonal Efficiency* (%)
Clare			
Before Retrofit (#1)	--	77.3	57.3
After Retrofit (#4)	44	76.4	72.4
(#6A)	38	79.5	75.5
Furnasman			
Before Retrofit (#7)	--	69.6	49.6
After Retrofit (#10A)	32	80.2	76.2
(#11A)	25	84.2	80.2
Bulloch-Centurion			
Before Retrofit (#14A)	--	73.2	53.2
After Retrofit (#16A)	32	81.3	77.3
(#17A)	29	83.1	79.1

Avg. Seasonal Efficiency Before Retrofit 53.4%

Avg. Seasonal Efficiency After Retrofit (with optimum orifice size) 78.3%

*Calculated by adjusting the Steady State Efficiencies based on the following loss estimates:

Off Cycle Losses:

Conventional	15%
I.D. Fan/Spark Ignition	4%

Pilot Losses:

Conventional	5%
I.D. Fan/Spark Ignition	0%

4.0 DISCUSSION OF RESULTS

The three furnaces were tested as natural draft appliances, as factory supplied (Clare and Furnasman) and as modified from oil to gas (Bulloch Centurion). The tests were repeated once the furnaces were retrofitted with spark ignition and induced draft fan systems. Testing was done to determine the effect of the retrofit on the furnace efficiency and to establish the safety of the retrofit. Results of the testing as provided by the Industrial Technology Centre (ITC) are given in Appendix 1. The test results calculated are summarized in Tables 1 and 2. A sample calculation of the results are explained in Appendix 5.

The behaviour of the retrofitted furnaces was observed during testing to ensure that retrofitting did not create a hazardous situation. As observed by the engineer in charge of the testing:

> "Flame appearance in all furnace models did not indicate change after retrofitting and no flame roll-outs were observed under normal gas pressure conditions where gas flow or power supply was interrupted. Pressure sensing devices, when properly adjusted, shut off gas supply to burners at blocked chimney outlet."

These observations would indicate that the controls on the retrofit furnace work, in a manner similar to a natural draft furnace, and are able to provide safe furnace operation under a variety of conditions.

The fan proving differential switch reacted well to physical blockage of the chimney by shutting off the gas valve until the blockage was removed.

Tests were carried out on the furnaces prior to retrofit to determine their performance. Blocked draft hood tests were carried out to assess the furnace operation without the inclusion of the dilution air supplied via the draft hood. This was necessary for the Clare and Furnasman units because it was not possible to measure the flue gas characteristics before the draft hood as these units use an integral draft hood. The draft hood for the Centurion was not integral and it was possible to perform a flue gas analysis both upstream and downstream of the draft hood.

Unfortunately, the results of Tests 1 and 2 were flawed for the Clare furnace due to an improper located access panel

which greatly reduced the flow of combustion air. This led to the incongruent result of higher air flow for the test with the blocked draft hood.

The Centurion furnace was tested (Test 13) as originally modified from oil to gas and found to be overfiring. It was then tested at a lower firing rate by changing the nozzle size (Test 14A). The venting configuration allowed a flue gas analysis to be performed both before (14A) and after the draft hood (14B). The large increase in excess air from 87% before the draft hood to 220% after the draft hood indicate the large affect the draft hood has in inducing dilution air up the chimney during operation.

Upon retrofit of the furnaces with induced draft fans and spark ignition and reconnection to the same venting system, the furnaces were retested. Each retrofit furnace was tested with 3 sizes of orifice plates, at two different voltages (120 and 102 V) and, for the Centurion, at three firing rates (3.48, 2.64 and 1.86 m^3/h).

The units performed as expected. As smaller orifice plates were installed, the air/fuel ratio and the related properties of excess air, exhausted flue volume decreased. As the volume of air exhausted and the excess air supplied decrease, the dew point, carbon monoxide (CO) level and steady state efficiency generally increases. (The CO levels are difficult to measure accurately at values below 0.01% and this may contribute to some minor fluctuations.) The tests at reduced voltage also provide the expected results with slightly reduced air fuel ratios, etc. for the lower voltage. (Tests 10A and B are an exception to this where a slight increase in air/fuel ratio, etc. was calculated. This may be caused by the small changes in the flue gas composition due to the voltage change being within the range of error of the testing equipment. The tests on the Centurion at the different firing rates show the flexibility of the interchangeable orifice plate system in setting up furnaces.

Correct selection of orifice plate size ensured that a negative pressure existed at the outlet of the induced draft fan. Therefore, combined venting of a conventional (draft hood equipped) hot water heater and an induced draft fan equipped furnace should not create any venting problems. This observation is backed up by an engineering report (No. ER26-47) prepared by the American Gas Association for Lennox Industries Inc..

An important test parameter is the maximum concentration of carbon monoxide (CO) which is present in the flue gas. The maximum allowable CO level, as set by National Standard CAN1-2.3-M84, is 0.04%. (Due to the nature of the combustion process and the effect of excess air on both the CO levels and the furnace steady state efficiency, CO levels at or near the maximum allowable levels are associated with higher furnace efficiencies.)

The maximum CO level was exceeded once (Test 12) and met on two other occasions (Test 1 and 17B). Test 12 was performed with the furnace's limit control* bypassed to permit true steady-state conditions to be achieved and a CO level of 0.05% was obtained. Tests 11A and 11B with the same orifice plate but with the limit control operating produced CO levels of 0.02 and 0.03% respectively. While the results for 11A and B are within maximum CO limits, the results of Test 12 would indicate that the high limit control was affecting the operation of the furnace and that the orifice plate used for Tests 11 and 12 was too small. The maximum CO level was reached in Test 1 (performed before the Clare furnace was retrofitted) due to an incorrectly located cover panel which restricted the flow of combustion air. Test 17B also produced the maximum level, however this resulted from reducing the size of the orifice plate and reducing the voltage level.

The results of Tests 6A and B, 11A and B, and 17A and B, indicate that under low flow conditions caused by small orifice plates, the voltage drop and the resulting further decrease in air flow has a significant affect on CO levels. The reduction in air flow caused by the voltage drop is quite small but at the conditions with the small orifice plate, the quantity of excess air is already low and the further reduction, albeit small, is significant.

As mentioned previously, the reduction in excess air caused an increase in the dew point temperature. The maximum increases were 10°C for the Clare 11°C for the Furnasman, and 12°C for the Centurion. The dew points increased to

*The limit control is an operating high limit in the supply air stream which will shut off the gas supply if a supply air temperature of 93°C (200°F) is reached. Since the supply air temperature during the tests did not approach 93°C, we believe that the limit control is in a location affected by radiant heat from the heat exchanger.

52°, 54° and 54° respectively while the chimney outlet temperature dropped to 125°C, 77°C and 71°C. The smaller temperature difference between the chimney outlet temperature and the gas dew point would indicate a greater chance of condensation, particularly during periods when climatic conditions would require only occasional operation of the furnace. Also, the vent (chimney) height in a residential application is likely to be higher than the 10 feet used in the test. This would further increase the potential for condensation. It should be noted that the potential problem of condensation in the vent is not peculiar to the retrofitted furnaces and could also be experienced with factory produced, induced draft fan equipped, appliances.

Significant increases in steady state efficiency were calculated for both the Furnasman and Centurion furnaces. A 14% increase in efficiency was evidenced for the Furnasman unit and a 10% increase for the Centurion. A smaller increase of 2% was seen for the Clare which was, as mentioned, initially tested with an improperly located access door.

A summary of representative test results for each furnace before and after retrofit are given in Table 2 for easy comparison. The results of post retrofit tests for the two smallest orifice sizes used are given to indicate the effect of orifice size selection on efficiency. The seasonal efficiencies were estimated by adjusting the calculated steady state efficiencies using loss estimates provided by CCRL. The estimates show an average increase in seasonal efficiency of 78.3 - 53.4% = 24.9% due to retrofit.

5.0 COST/BENEFIT ANALYSIS

5.1 COSTS

Materials

A)	Spark Ignition Module, Pilot Burner/Igniter Sensor, Ignition Cable	$95
B)	Combination Gas Valve	$55
C)	Pressure Switch, Fan Control Centre	$75
D)	Induced Draft Fan and Flue Transition Box	$100
E)	Taxes and Mark-Up	$65
	Sub-Total	$390

Labour

A)	Installation	$140
B)	Wiring	$130
C)	Testing	$50
D)	Warranty Provision (1 Year)	$70
	Sub-Total	$390
	Total Materials and Labour	$780

The above costs were arrived at through discussions with equipment suppliers and Furnasman Ltd. and were based on a contractor purchasing materials from trade wholesalers and performing the retrofit on a single furnace in a customer's home. However, we were advised that if this method of retrofit became common, as contractors became familiar with the retrofit, contractors could reduce their labour charges by and estimated $80 (reducing the cost to $700). We would also expect the industry to respond with lower priced retrofit kits to further reduce the cost. However for purposes of our cost/benefit analysis we will assume that the cost of the retrofit would be $700.

5.2 SAVINGS AND SIMPLE PAYBACK

Before Retrofit

Average annual heating gas consumption (Winnipeg) = 120 MCF

Average annual heating cost = 120 MCF x $5.16/MCF (based on a blended gas rate of $5.16/MCF) = $619

After Retrofit

Average annual heating gas consumption (Winnipeg) (assuming a seasonal efficiency increase from 53.4% to 78.3%) = 82 MCF

Annual Savings = (120 - 82) x $4.628/MCF (based on the price of gas consumed in the 50 to 150 MCF/mth block) = $175

$$\text{Simple Payback Period} = \frac{\text{Retrofit Cost}}{\text{Annual Savings}} = \frac{\$700}{\$175} = 4.0 \text{ years}$$

6.0 CONCLUSIONS

It is concluded that it is technically feasible to perform the field retrofit of conventional gas fired furnaces with intermittent spark ignition and induced draft fans using readily available components. In addition, it was found that the retrofit increased the steady state efficiencies of standard furnaces tested by 2.2, 9.9, and 14.6 percentage points. We also estimated that an average seasonal efficiency improvement of approximately twenty-five percentage points (i.e. 53.4 to 78.3) was obtained for the three furnaces retrofitted.

The simple payback period of performing the retrofit (based on our cost estimates and the seasonal efficiency improvements calculated) is approximately 4 years in Winnipeg.

Our results showed that during steady state operating conditions, the flue gas temperature at the chimney outlet was always higher than the dewpoint temperature. However, during warm-up or cooldown periods, the flue gases could conceivably condense in the chimney. The effect of this condensing requires further study.

Test #1 Pre-Retrofit

Furnace Model: Clare

Project #06565

January 21, 1986

Measured Parameter	Unit	Time	
		11:26	11:41
Air inlet temperature	°C	14.8	16
Air discharge temperature	°C	67	69
Flue temperature at the flue collar	°C	159	160
Flue temperature at the chimney outlet	°C	122	124
Carbon monoxide	%	0.04	0.03
Carbon dioxide	%	4.7	4.4
Oxygen	%	13.2	13.5
Natural gas flow rate	m^3/h (CFH)	4.54 (160.5)	
Differential pressure at the burner bed	Pa (in W.C.)	<2.5 (<0.01)	
Differential pressure at the flue collar	Pa (in W.C.)	5 (0.02)	

NOTES:

1) Test was performed at the same conditions as during the Test #2 except the draft hood was opened

Test #2 Pre-Retrofit

Furnace Model: Clare

Project #06565

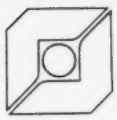
January 21, 1986

Measured Parameter	Unit	Time	
		10:20	10:35
Air inlet temperature	°C	16.1	16.2
Air discharge temperature	°C	65.3	67.0
Flue temperature at the flue collar	°C	225	227
Flue temperature at the chimney outlet	°C	188	188
Carbon monoxide	%	0.03	0.03
Carbon dioxide	%	4.6	4.6
Oxygen	%	13.6	13.5
Natural gas flow rate	m^3/h (CFH)	4.54 (160.5)	
Differential pressure at the burner bed	Pa (in W.C.)	2.5 (<0.01)	
Differential pressure at the flue collar	Pa (in W.C.)	7.6 (0.03)	

NOTES:

1) Test was performed with blocked draft hood.

2) Furnace blowers created negative pressure causing "starvation" of combustion and air contamination with combustion products. To conduct the test, both air return inlets remained open for negative pressure reduction



Test #3 Post Retrofit

Furnace Model: Clare

Project #06565

February 10, 1986

Measured Parameters Under Steady-State Conditions	Unit	Test Line Voltage	
		120	102
Air inlet temperature	°C	14.7	-
Air outlet temperature	°C	59.0	-
Flue temperature at the flue collar	°C	223	-
Flue temperature at the chimney inlet	°C	178	-
Flue temperature at the chimney outlet	°C	153	-
Carbon monoxide	%	0.006	-
Carbon dioxide	%	4.9	-
Oxygen	%	12.2	-
Differential pressure at the collar tap	Pa (in W.C.)	Cannot detect	-
Gas flow rate	m^3/h (CFH)	4.19 (148)	
Orifice size	mm (in)	50.8 (2)	

NOTE: Tests were performed with uncovered combustion chamber

Test #4 Post Retrofit

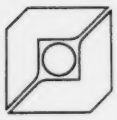
Furnace Model: Clare

Project #06565

February 10, 1986

Measured Parameters Under Steady-State Conditions	Unit	Test Line Voltage	
		120	102
Air inlet temperature	°C	14.0	-
Air outlet temperature	°C	61.0	-
Flue temperature at the flue collar	°C	240	-
Flue temperature at the chimney inlet	°C	163	-
Flue temperature at the chimney outlet	°C	130	-
Carbon monoxide	%	0.008	-
Carbon dioxide	%	6.4	-
Oxygen	%	9.3	-
Differential pressure at the collar tap	Pa (in W.C.)	-5 (-0.02)	-
Gas flow rate	m^3/h (CFH)	4.19 (148)	
Orifice size	mm (in)	44.4 (1.75)	

NOTE: Tests were performed with uncovered combustion chamber



Test #5 Post Retrofit

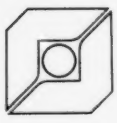
Furnace Model: Clare

Project #06565

February 11, 1986

Measured Parameters Under Steady-State Conditions	Unit	Test Line Voltage	
		120	102
Air inlet temperature	°C	17.2	-
Air outlet temperature	°C	64.0	-
Flue temperature at the flue collar	°C	220	-
Flue temperature at the chimney inlet	°C	152	-
Flue temperature at the chimney outlet	°C	125	-
Carbon monoxide	%	0.01	-
Carbon dioxide	%	6.6	-
Oxygen	%	9.1	-
Differential pressure at the collar tap	Pa (in W.C.)	-7 (-0.03)	-
Gas flow rate	m^3/h (CFH)	4.19 (148)	
Orifice size	mm (in)	38.1 (1.5)	

NOTE: Tests were performed with uncovered combustion chamber



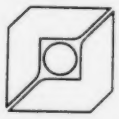
Test #6 Post Retrofit
Furnace Model: Clare

Project #06565

February 26, 1986

Measured Parameters Under Steady-State Conditions	Unit	A	B
		Test Line Voltage	
		120	102
Air inlet temperature	°C	21.5	23.4
Air outlet temperature	°C	71.0	73.0
Flue temperature at the flue collar	°C	220	216
Flue temperature at the chimney inlet	°C	154	150
Flue temperature at the chimney outlet	°C	130	127
Carbon monoxide	%	0.007	0.02
Carbon dioxide	%	7.4	7.7
Oxygen	%	7.5	7.0
Differential pressure at the collar tap	Pa (in W.C.)	-9 (-0.035)	-10 (-0.04)
Gas flow rate	m^3/h (CFH)	4.19 (148)	
Orifice size	mm (in)	38.1 (1.5)	
Pressure drop on orifice	kPa (in W.C.)	0.35 (1.4)	0.20 (0.8)

NOTE: Tests were performed with uncovered combustion chamber



Test #7 Pre-Retrofit

Furnace Model: Furnasman

Project #06565

January 20, 1986

Measured Parameter	Unit	Time	
		2:51	3:06
Air inlet temperature	°C	22.2	19.6
Air discharge temperature	°C	67.5	64.5
Flue temperature at the flue collar	°C	254	259
Flue temperature at the chimney outlet	°C	135	136
Carbon monoxide	%	<0.01	<0.01
Carbon dioxide	%	4.1	4.1
Oxygen	%	13.4	13.7
Natural gas flow rate	m^3/h (CFH)	2.37 (83.7)	
Differential pressure at the burner bed	Pa (in W.C.)	5 (0.02)	
Differential pressure at the flue collar	Pa (in W.C.)	5 (0.02)	

NOTES:

1) Test was performed with the draft hood open

Test #8 Pre-Retrofit

Furnace Model: Furnasman

Project #06565

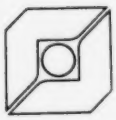
January 20, 1986

Measured Parameter	Unit	Time	
		2:10	2:30
Air inlet temperature	°C	20.5	22.0
Air discharge temperature	°C	64.4	64.7
Flue temperature at the flue collar	°C	308	310
Flue temperature at the chimney outlet	°C	152	161
Carbon monoxide	%	<0.01	<0.01
Carbon dioxide	%	5.1	4.9
Oxygen	%	11.5	11.6
Natural gas flow rate	m^3/h (CFH)	2.37 (83.7)	
Differential pressure at the burner bed	Pa (in W.C.)	not detectable	
Differential pressure at the flue collar	Pa (in W.C.)	5 (0.02)	

NOTES:

1) Test was performed with blocked draft hood

2) Furnace was equipped with a provision for primary combustion air control only



Test #9 Post-Retrofit

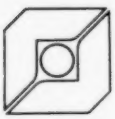
Furnace Model: Furnasman

Project #06565

February 24, 1986

Measured Parameters	Unit	A	B
		Test Line Voltage	
		120	102
Air inlet temperature	°C	22.8	20.8
Air outlet temperature	°C	60.5	59.9
Flue temperature at the flue collar	°C	250	241
Flue temperature at the chimney inlet	°C	230	224
Flue temperature at the chimney outlet	°C	174	165
Carbon monoxide	%	0.01	0.01
Carbon dioxide	%	3.7	4.0
Oxygen	%	14.1	14.0
Differential pressure at the collar tap	Pa (in W.C.)	-2.5 (-0.01)	-4.0 (-0.015)
Gas flow rate	m^3/h (CFH)	2.27 (80.2)	
Orifice size	mm (in)	38.1 (1.5)	
Pressure drop on orifice	kPa (in W.C.)	0.07 (0.28)	0.04 (0.16)

NOTE: Temperature equilibrium was not achieved due to action of limit control. Measured temperatures represent maximum values obtained during the test.



Test #10 Post Retrofit

Furnace Model: Furnasman

Project #06565

February 24, 1986

Measured Parameters	Unit	A	B
		Test Line Voltage	
		120	102
Air inlet temperature	°C	22.0	24.0
Air outlet temperature	°C	66.0	64.1
Flue temperature at the flue collar	°C	198	188
Flue temperature at the chimney inlet	°C	170	161
Flue temperature at the chimney outlet	°C	108	105
Carbon monoxide	%	0.007	0.007
Carbon dioxide	%	6.8	6.9
Oxygen	%	8.3	8.5
Differential pressure at the collar tap	Pa (in W.C.)	-4.0 (-0.016)	-4.0 (-0.016)
Gas flow rate	m^3/h (CFH)	2.27 (80.2)	
Orifice size	mm (in)	31.7 (1.25)	
Pressure drop on orifice	kPa (in W.C.)	0.25 (1.0)	0.23 (0.92)

NOTE: Temperature equilibrium was not achieved due to action of limit control. Measured temperatures represent maximum values obtained during the test.

Test #11 Post Retrofit

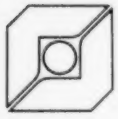
Furnace Model: Furnasman

Project #06565

February 25, 1986

Measured Parameters	Unit	A Test Line Voltage 120	B Test Line Voltage 102
Air inlet temperature	°C	23.0	23.0
Air outlet temperature	°C	66.0	66.0
Flue temperature at the flue collar	°C	148	150
Flue temperature at the chimney inlet	°C	124	123
Flue temperature at the chimney outlet	°C	77	77
Carbon monoxide	%	0.02	0.03
Carbon dioxide	%	8.3	8.4
Oxygen	%	5.5	5.4
Differential pressure at the collar tap	Pa (in W.C.)	-4 (-0.016)	-4 (-0.016)
Gas flow rate	m^3/h (CFH)	2.27 (80.2)	
Orifice size	mm (in)	25.4 (1.0)	
Pressure drop on orifice	kPa (in W.C.)	0.29 (1.16)	0.25 (1.0)

NOTE: Temperature equilibrium was not achieved due to action of limit control. Measured temperatures represent maximum values obtained during the test.



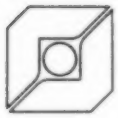
Test #12 Post Retrofit
Furnace Model: Furnasman

Project #06565

February 25, 1986

Measured Parameters Under Steady State Conditions	Unit	Test Line Voltage	
		120	102
Air inlet temperature	°C	26.0	-
Air outlet temperature	°C	68.0	-
Flue temperature at the flue collar	°C	156	-
Flue temperature at the chimney inlet	°C	132	-
Flue temperature at the chimney outlet	°C	81	-
Carbon monoxide	%	0.05	-
Carbon dioxide	%	8.4	-
Oxygen	%	5.2	-
Differential pressure at the collar tap	Pa (in W.C.)	-4 (-0.016)	-
Gas flow rate	m^3/h (CFH)	2.27 (80.2)	
Orifice size	mm (in)	25.4 (1.0)	
Pressure drop on orifice	kPa (in W.C.)	0.29 (1.16)	-

NOTE: Test was performed with by-passed limit control.



Test #13 Pre-Retrofit

Furnace Model: Centurian

Project #06565

January 20, 1986

Measured Parameter	Unit	Time	
		10:36	10:51
Air inlet temperature	°C	22.5	22.5
Air discharge temperature	°C	67.2	68.6
Flue temperature before draft hood	°C	329	327
Flue temperature after draft hood	°C	242	242
Carbon monoxide	%	0.03	0.03
Carbon dioxide	%	10.0	10.0
Oxygen	%	2.7	2.7
Natural gas flow rate	m^3/h (CFH)	3.48 (123)	
Differential pressure at the burner bed	Pa (in W.C.)	<2.5 (<0.01)	
Differential pressure before draft hood	Pa (in W.C.)	<2.5 (<0.01)	
Differential pressure after draft hood	Pa (in W.C.)	<2.5 (<0.01)	

NOTES:

1) Furnace was equipped with provisions for primary and secondary combustion air controls

2) Limit control was by-passed to obtain desired temperature of discharged air

3) Test was performed with completely closed secondary combustion air damper

Test #14 Pre-Retrofit

Furnace Model: Centurian

Project #06565

January 20, 1986

Measured Parameter	Unit	Time A 4:05	Time B 4:20
Air inlet temperature	°C	24.0	25.5
Air discharge temperature	°C	71.3	72.5
Flue temperature at the chimney outlet	°C	106	107
Flue temperature at the flue collar	°C	284	279
Flue temperature after the draft hood	°C	158	154
Flue constituents at the flue collar:			
Carbon monoxide	%	<0.01	<0.01
Carbon dioxide	%	5.4	6.0
Oxygen	%	11.3	10.3
Flue constituents after the draft hood:			
Carbon monoxide	%	<0.01	<0.01
Carbon dioxide	%	3.4	3.4
Oxygen	%	15.0	15.0
Natural gas flow rate	m^3/h (CFH)	1.8 (63.7)	
Differential pressure at the burner bed	Pa (in W.C.)	<2.5 (<0.01)	
Differential pressure at the flue collar	Pa (in W.C.)	<2.5 (<0.01)	
Differential pressure after draft hood	Pa (in W.C.)	<2.5 (<0.01)	

NOTES:

1) Test performed as specified in Test #1 except the orifice was replaced with the smaller size

Test #15 Post Retrofit

Furnace Model: Centurian

Project #06565

February 25, 1986

Measured Parameters Under Steady State Conditions	Unit	A	B
		Test Line Voltage	
		120	102
Air inlet temperature	°C	32	32
Air outlet temperature	°C	104	106
Flue temperature at the flue collar	°C	290	289
Flue temperature at the chimney inlet	°C	198	169
Flue temperature at the chimney outlet	°C	120	117
Carbon monoxide	%	0.008	0.01
Carbon dioxide	%	8.3	8.5
Oxygen	%	5.3	4.8
Differential pressure at the collar tap	Pa (in W.C.)	-4 (-0.016)	-4 (-0.016)
Gas flow rate	m^3/h (CFH)	2.64 (93.3)	
Orifice size	mm (in)	38.1 (1.5)	
Pressure drop on orifice	kPa (in W.C.)	0.25 (1.0)	0.20 (0.8)

NOTE: Test was performed with nozzle 9.5 mm diameter.

Test # 16 Post Retrofit

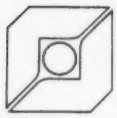
Furnace Model: Centurian

Project #06565

February 25, 1986

Measured Parameters	Unit	A Test Line Voltage 120	B Test Line Voltage 102
Air inlet temperature	°C	27	27
Air outlet temperature	°C	81	82
Flue temperature at the flue collar	°C	198	203
Flue temperature at the chimney inlet	°C	133	134
Flue temperature at the chimney outlet	°C	80	80
Carbon monoxide	%	0.008	0.008
Carbon dioxide	%	7.3	7.4
Oxygen	%	6.9	6.8
Differential pressure at the collar tap	Pa (in W.C.)	-4 (-0.016)	-4 (-0.016)
Gas flow rate	m^3/h (CFH)	1.86 (65.7)	
Orifice size	mm (in)	31.7 (1.25)	
Pressure drop on orifice	kPa (in W.C.)	0.27 (1.0)	0.24 (0.96)

NOTE: Test was performed with nozzle 8.7 mm diameter.



Test #17 Post Retrofit

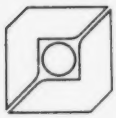
Furnace Model: Centurian

Project #06565

February 25, 1986

Measured Parameters	Unit	A	B
		Test Line Voltage	
		120	102
Air inlet temperature	°C	27	27
Air outlet temperature	°C	85	85
Flue temperature at the flue collar	°C	180	183
Flue temperature at the chimney inlet	°C	116	117
Flue temperature at the chimney outlet	°C	71	71
Carbon monoxide	%	0.01	0.04
Carbon dioxide	%	8.4	8.7
Oxygen	%	5.3	4.7
Differential pressure at the collar tap	Pa (in W.C.)	-3 (-0.01)	-3 (-0.01)
Gas flow rate	m^3/h (CFH)	1.86 (65.7)	
Orifice size	mm (in)	28.6 (1.125)	
Pressure drop on orifice	kPa (in W.C.)	0.27 (1.08)	0.23 (0.92)

NOTE: Test was performed with nozzle 8.7 mm diameter.



List of Testing Equipment

1. Flue Gas Analysis Equipment

O_2
- Horiba Model PMA-200
- Ranges: 0 to 15%/25%
- Accuracy, repeatability, zero/span drift: ± 1%/24 hour full scale

CO_2
- Horiba Model PIR-2000
- Ranges: 0 to 5%/15%/25%
- Accuracy, zero/span drift: ± 1%/24 hour full scale
- Repeatability: ± 0.5% full scale

CO
- Horiba Model PIR-2000
- Ranges: 0 to 2%/6%/10%
- Accuracy, zero/span drift: ± 1%/24 hour full scale
- Repeatability: ± 0.5% full scale

2. Temperature Measurement

K-type thermocouple wire and FLUKE 1720A, 2400A, 2401A, data acquisition system
- Accuracy 0.5°C

3. Gas Flow Measurement

Precision testing gas meter type RC-230, Rockwell International of Canada Ltd. Resolution 0.01 CF

4. Pressure Difference Measurement

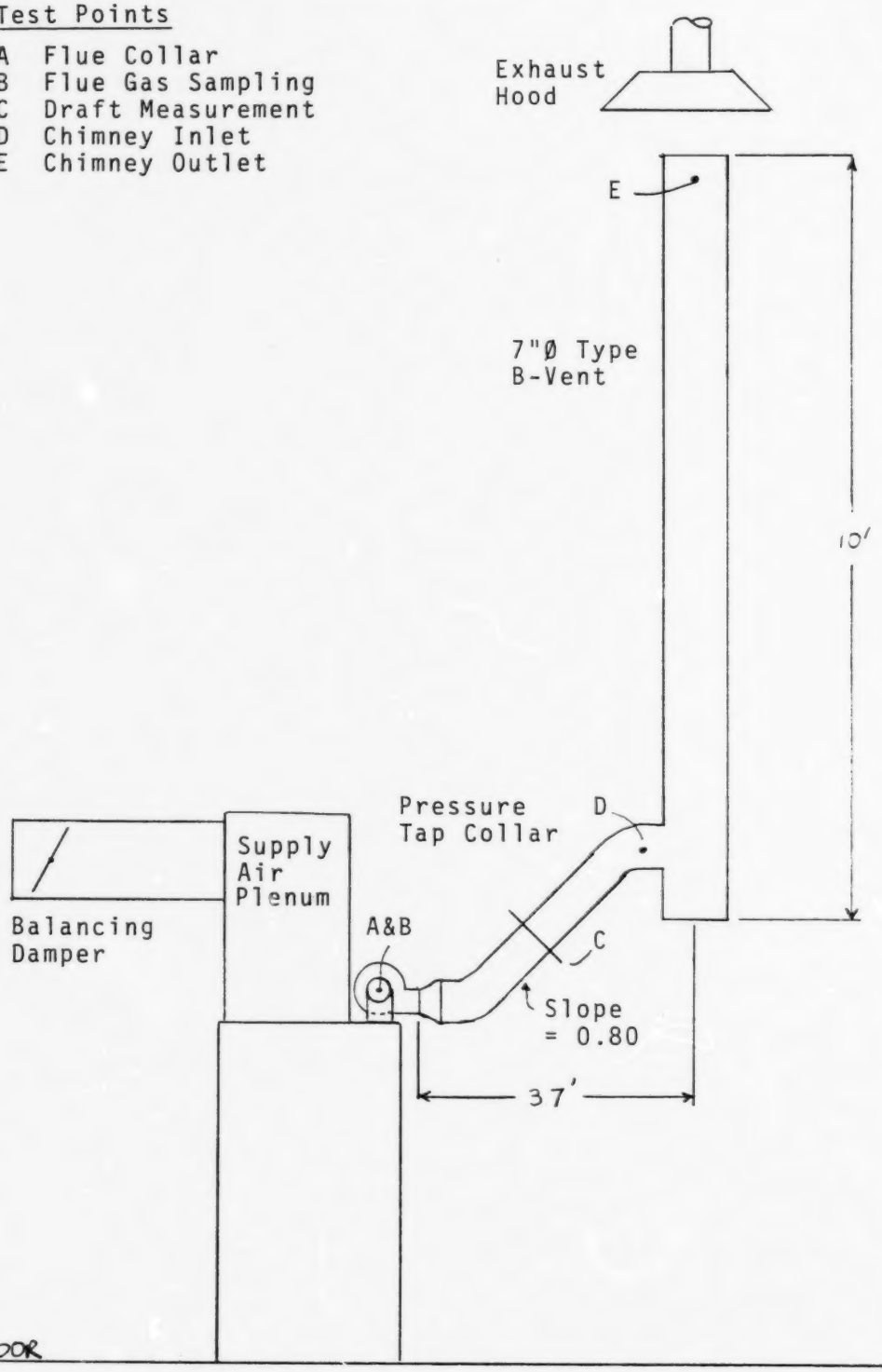
Draft measuring device, "Draftrite" Bacharach Instrument Co. - Ranges from 0 to 0.08 in W.C.

5. Inclined Manometer

Range: 0 to 125/250/500/2500 Pa
Resolution: 0.5/1/2/10 Pa respectively

Test Points

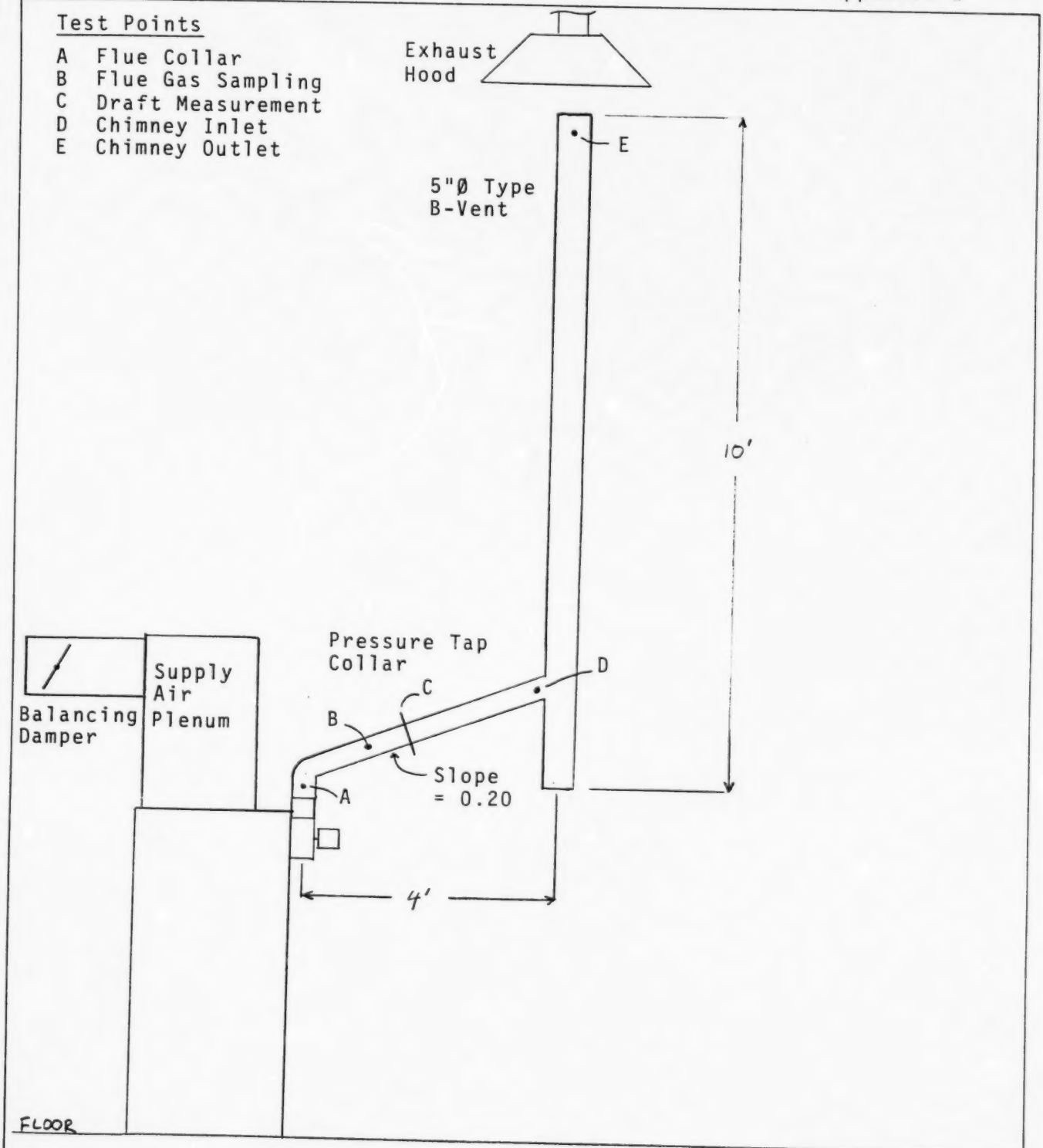
A Flue Collar
B Flue Gas Sampling
C Draft Measurement
D Chimney Inlet
E Chimney Outlet



				THE CONSERVER GROUP INC. ENERGY ENGINEERS 356 Hargrave St., Winnipeg, Can. R3B 2J9 Tel.. (204) 956-2129
	REVISIONS	DATE	APP.	
DESIGNED BY: GV		DATE		Clare (GF #1) Vent Arrangement
SHEET ___ OF ___	DWG. No. ___	NTS		

Test Points

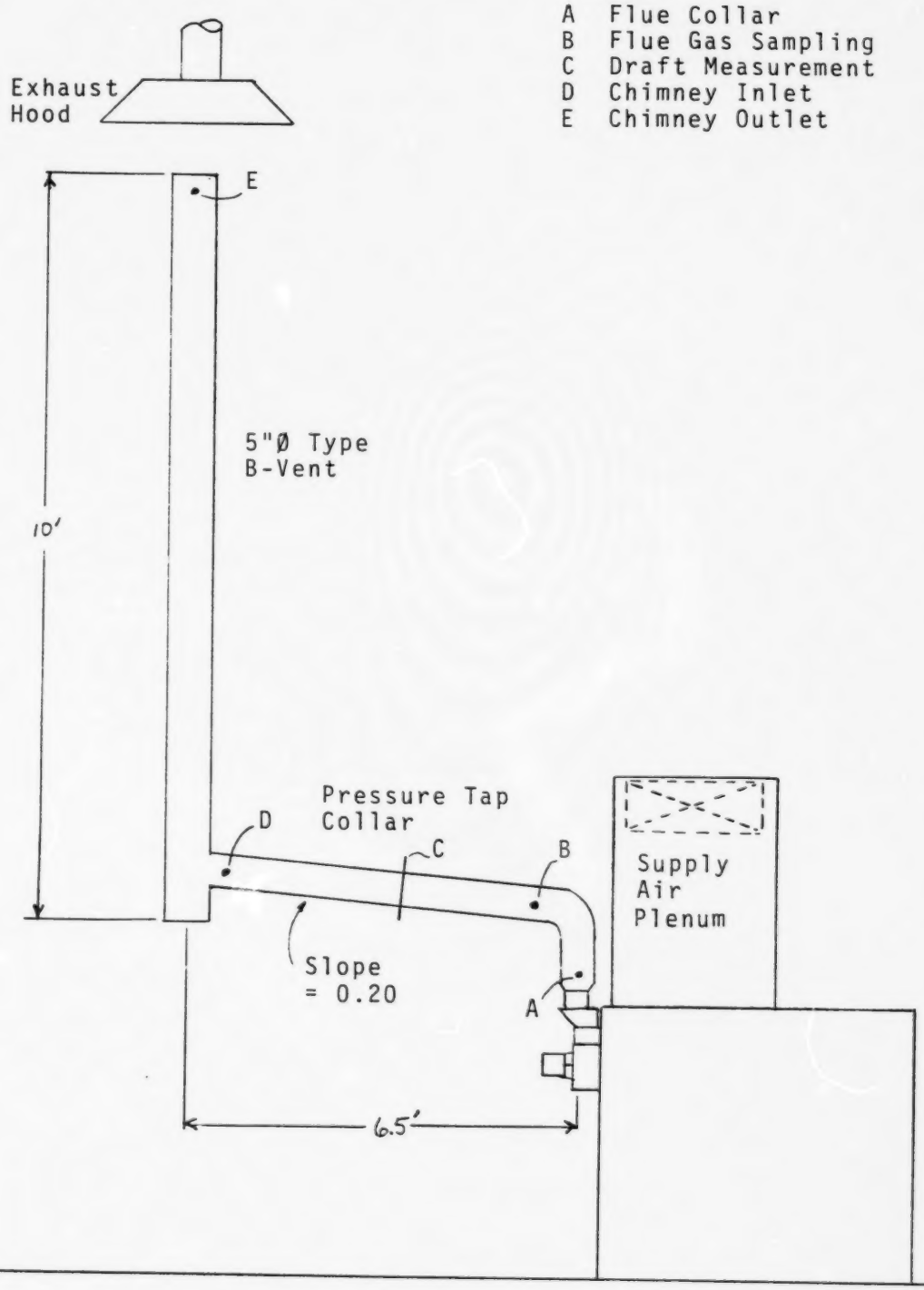
A Flue Collar
B Flue Gas Sampling
C Draft Measurement
D Chimney Inlet
E Chimney Outlet



				THE CONSERVER GROUP INC. ENERGY ENGINEERS 356 Hargrave St., Winnipeg, Can. R3B 2J9 Tel.: (204) 956-2129
	REVISIONS	DATE	APP.	
DESIGNED BY: AW		DATE		Furnasman (GF #2) Vent Arrangement
SHEET ___ OF ___	DWG. No. ___	NTS		

Test Points

A Flue Collar
B Flue Gas Sampling
C Draft Measurement
D Chimney Inlet
E Chimney Outlet



				THE CONSERVER GROUP INC. ENERGY ENGINEERS 356 Hargrave St., Winnipeg, Can. R3B 2J9 Tel.: (204) 956-2129
	REVISIONS	DATE	APP.	
DESIGNED BY:		DATE		Bulloch Centurion (GF #3) Vent Arrangement
SHEET ___ OF ___	DWG. No. ___	NTS		

DESIGN SPECIFICATION FOR RETROFITTING THREE STANDARD-EFFICIENCY GAS FURNACES WITH INDUCED DRAFT FANS AND INTERMITTENT SPARK IGNITION

I. GENERAL

Two gas furnaces and one gas conversion oil furnace which are presently equipped with continuous pilot lights and draft diverter hoods shall be modified by installing intermittent spark ignition and induced draft fans in order to create a "mid-efficiency" furnace. The three furnaces to be retrofitted are:

GF#1 Clare Model MBG200 - 200,000 Btuh gas input

GF#2 Furnasman Model HG90-2W - 90,000 Btuh gas input

GF#3 Bulloch Centurion (oil-gas conversion) c/w Barber-Aero Model UPB190 gas burner.

1.0 Description of Work

1.1 Sheet Metal Alterations and Induced Draft Fan Installation

.1 For furnaces GF#1 and GF#2

(i) Block off the inlet of the draft hood as shown in the sketch in Figure 1 in order that the flue gas path is completely isolated and cannot induce dilution air from the building. (In effect, a flue "header" on the outlets from the heat exchangers shall be created; there are five heat exchangers on GF#1 and two on GF#2.)

(ii) Block off the existing flue outlet on the top of the header.

(iii) Caulk all seams and holes in the flue "header" with high temperature sealant to ensure complete isolation of the flue gases.

(iv) Install the induced draft fan on the front of the new "header" as shown in Figure 1.

.2 Install an induced draft fan at the horizontal discharge of furnace GF#3's heat exchanger as shown in Figure 2.

.3 Fabricate sheet metal transition boxes for all three furnaces, complete with pressure sensing tubes as shown

in Figure 3. These are to be bolted to the flanged outlets of each induced draft fan and act as a transition into the 3"Ø breeching. Orifice plates of 3"Ø outside diameter with (centred) holes of between 3/4" and 2" in diameter in 1/8" increments shall also be fabricated.

.4 Repair the sheet metal enclosure of furnace GF#1 to ensure a good separation between the burner bed and the supply fan enclosure.

1.2 Gas Valve and Controls

.1 Remove existing - gas valve assemblies
- pilot burners

.2 Install - intermittent pilot control module
- combination gas valve and controls
- pilot burner/igniter/sensor
- pressure switch (flow proving device)

.3 Install new fan control centres on furnaces GF#2 and GF#3. (GF#1 has an existing one).

.4 Install all electrical/control wiring as shown in the Figure 4 wiring diagram to provide the following sequence of operation:

1) Space thermostat calls for heat (i.e. its contacts close).

2) Induced draft (I.D.) fan starts.

3) Pressure (fan proving) switch contacts close. (If pressure switch does not prove, sequence stops.)

4) Spark generator is energized, the pilot valve operator opens and the pilot burner lights.

5) Pilot sensor is satisfied by pilot burner heat.

6) Main gas valve opens and spark generator is de-energized.

7) Main burner flame ignites.

8) When the hot air supply temperature reaches its setpoint, the blower thermostat starts the blower.

9) Furnace operation continues as long as the following conditions are met:

i) space thermostat continues to call for heat;
ii) burner remains lit;
iii) air proving switch detects sufficient air flow;
iv) temperature at high limit control remains below its 200°F setpoint.

10) When the space thermostat is satisfied, the main gas valve and pilot valve are shut and the I.D. fan is shut off.

11) The supply blower continues to operate until the supply air temperature drops to the setpoint of the blower thermostat (normally 120°F on, 90°F off).

II. PRODUCTS

1. Intermittent Pilot Control Module

.1 Acceptable Product: Honeywell Model S86E, F, or G or approved equivalent.

.2 Performs the following functions when activated:

(i) Safe-start check which tests internal components for a false flame condition.

(ii) Generates a potential of 15,000V (open circuit) for spark ignition of the pilot burner.

(iii) Opens the pilot valve of the gas control.

(iv) Discontinues ignition when the pilot flame is established.

(v) After proving the presence of the pilot flame, opens the main valve.

(vi) On a power loss, shuts down. When power is restored, new startup begins.

(vii) On a loss of flame, main gas is shut-off and trial for ignition starts.

2. Combination Gas Valve

.1 Acceptable Product: Honeywell Model VR 8440P or approved equivalent.

.2 Combines an ON-OFF manual gas valve, two automatic valve operators and servo pressure regulator.

.3 Equipped with pilot flow adjustment and outlet pressure tapping.

.4 Step opening pressure regulator.

3. Pilot Burner/Igniter-Sensor

.1 Acceptable Product: Honeywell Model Q345 or approved equivalent.

.2 Conventional style pilot burner fitted with an insulated rod and ground strap to provide for igniting and sensing the presence of the pilot flame.

4. Differential Pressure Switch

.1 Acceptable Product: Penn Model P32AF-2 or approved equivalent.

.2 Adjustable, Range 0.05 to 5.0 in. w.c. Single Pole, Double Throw (SPDT).

5. Fan Control Centre

.1 Acceptable Product: White-Rodgers Type 8A05A-1.

.2 Combination SPDT relay and 40VA transformer (120:24v).

6. Induced Draft Fan

.1 Acceptable Product: Torin Model SC-416-3926 or approved equivalent.

.2 Centrifugal blower c/w 4½" ø, 1-3/4" W wheel and 3000 RPM, 0.8 Amp, 120V motor.

.3 Capable of 40 CFM @ 1.30 in. w.c. static pressure.

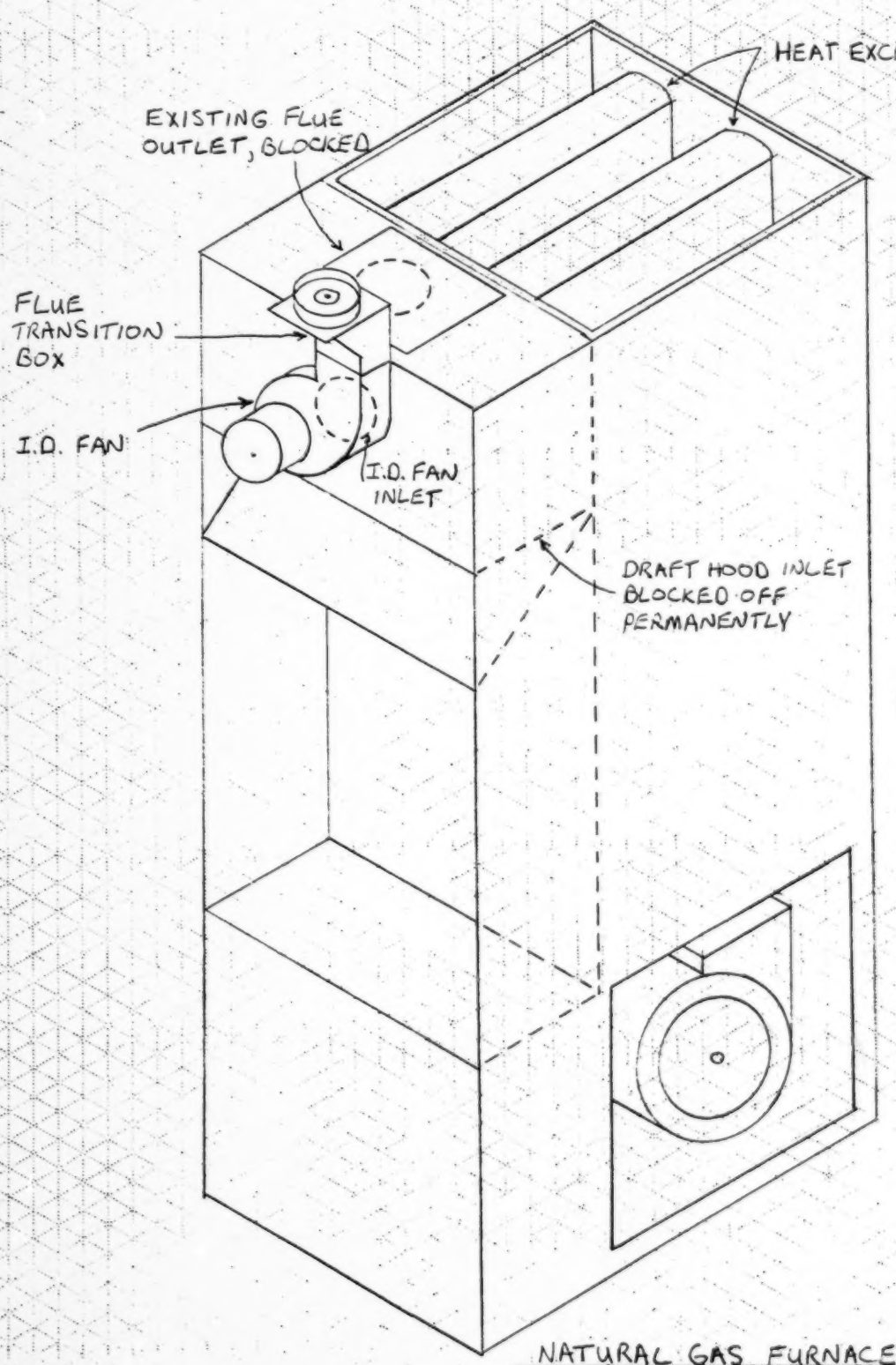
III. EXECUTION

.1 All work must comply with all acceptable codes, conform with good practice and be done with good workmanship.

.2 All components shall be installed and tested in accordance with the manufacturer's instructions.

.3 Installation of automatic intermittent pilot igniter systems shall meet ANSI STANDARD Z21.71-1981.

.4 If the pilot control module is mounted on a hot surface of the furnace it shall not be flush mounted (i.e. spacers shall be used on the mounting screws).



NATURAL GAS FURNACES GF#1 & #2 (NTS)

DATE JAN. '86

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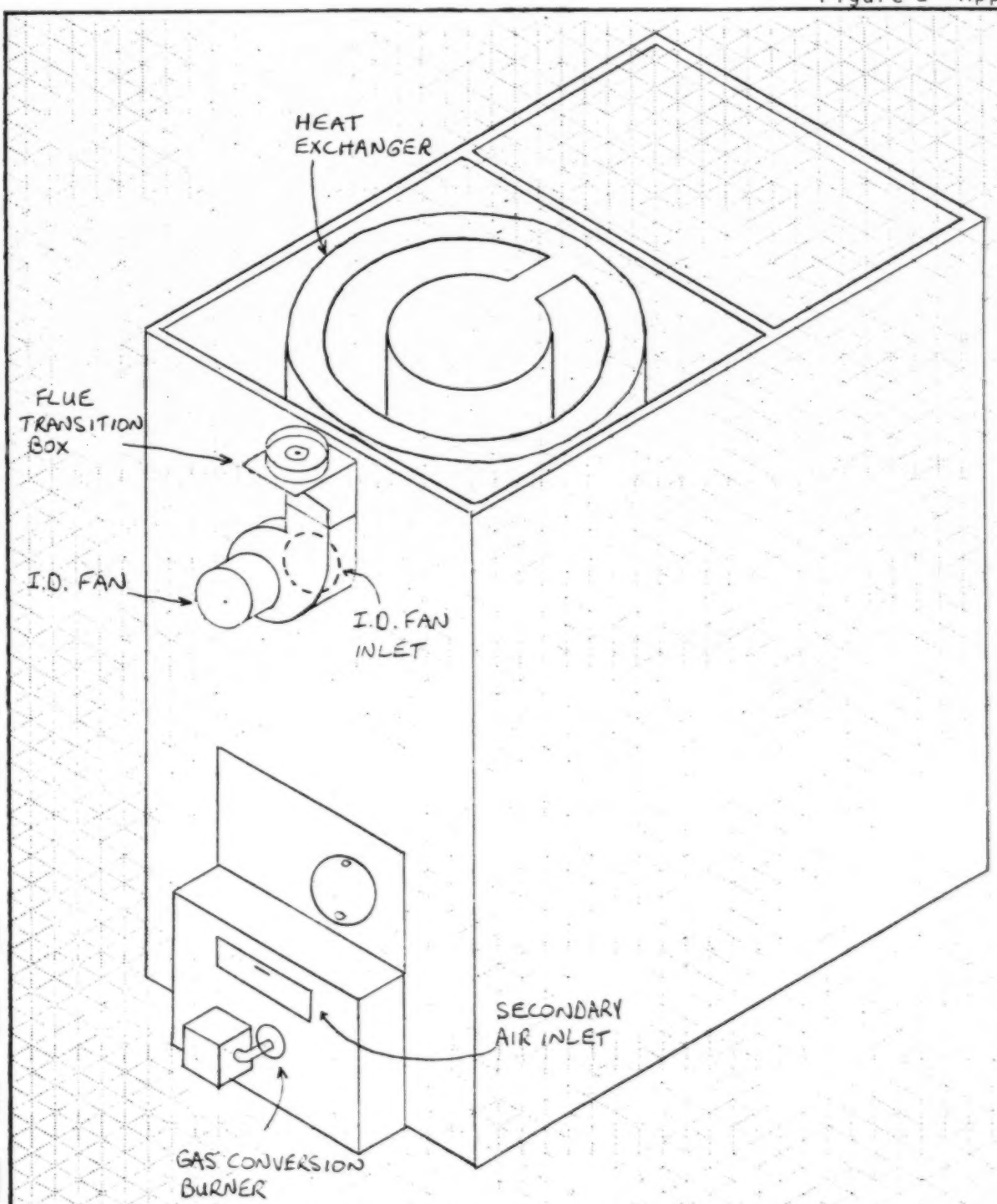

OIL CONVERSION FURNACE GF#3.

(NTS)

DATE JAN. '86

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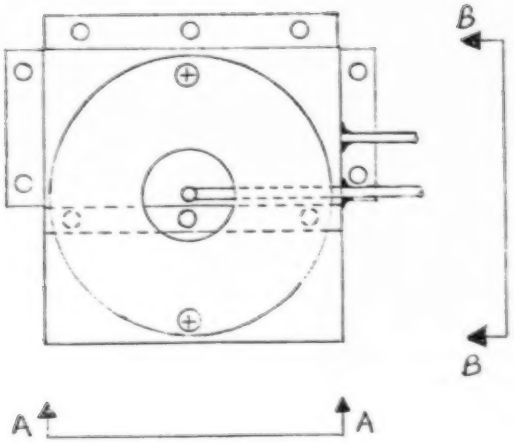
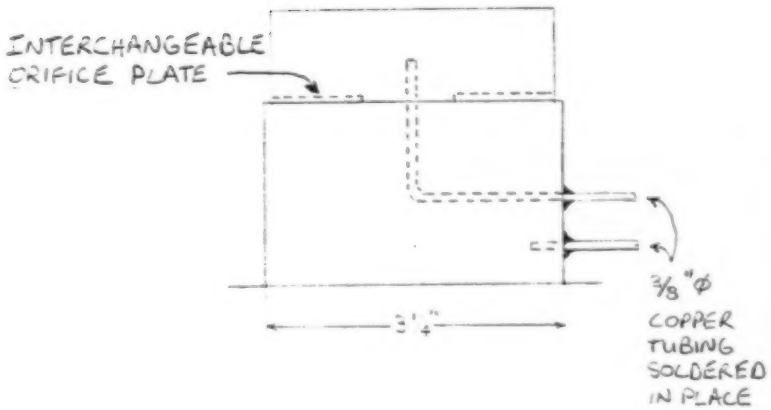
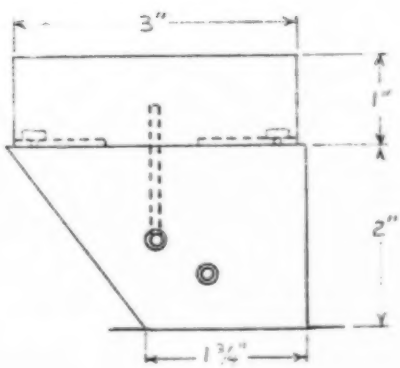


PLAN VIEW
(NTS)

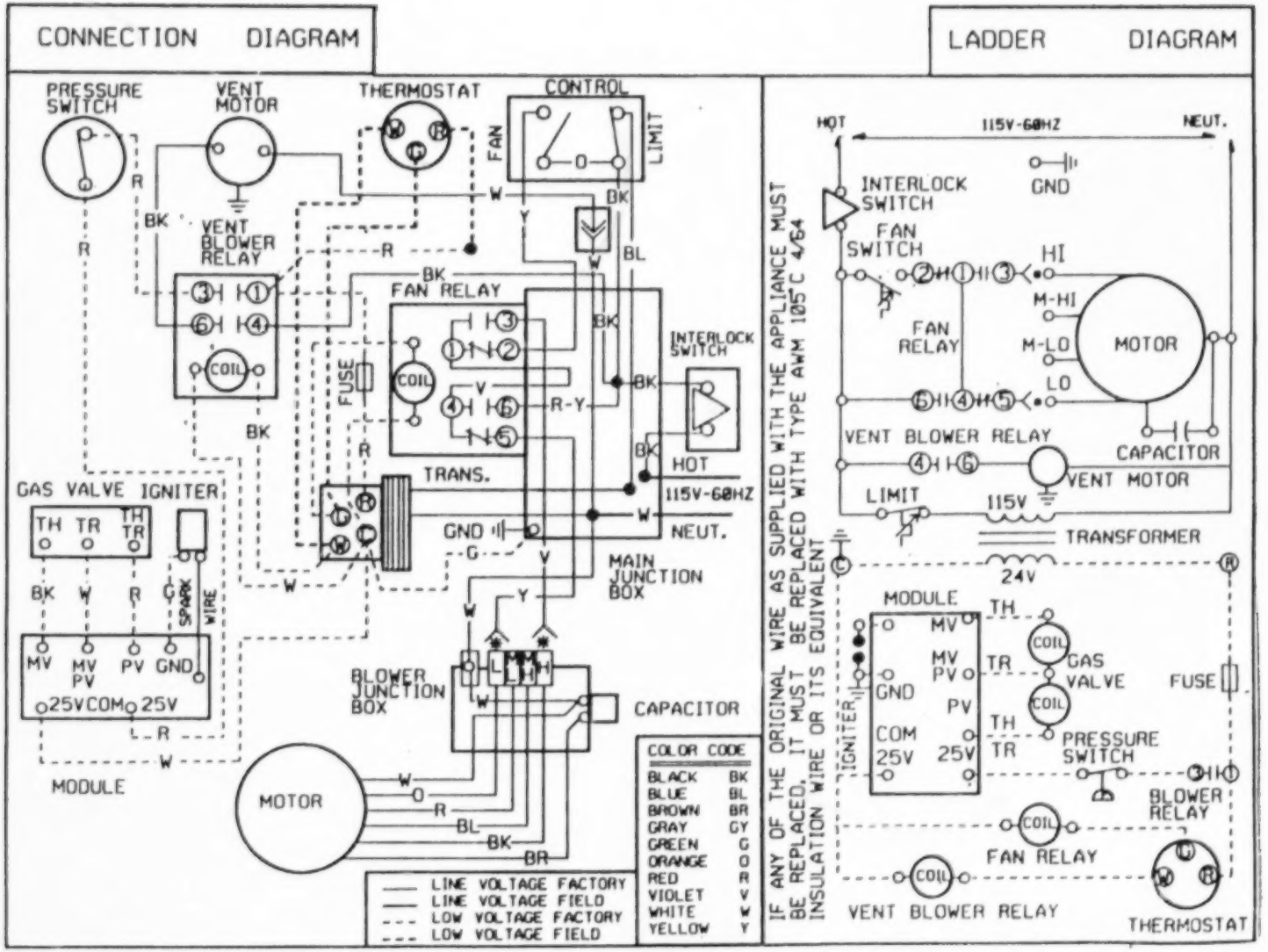


VIEW A-A
(NTS)



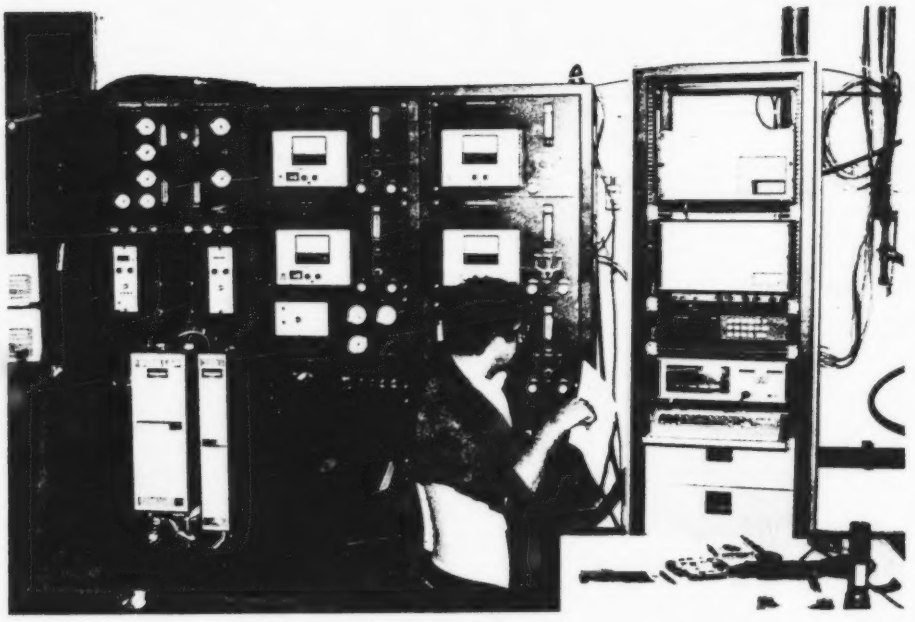
VIEW B-B
(NTS)

FLUE TRANSITION BOX

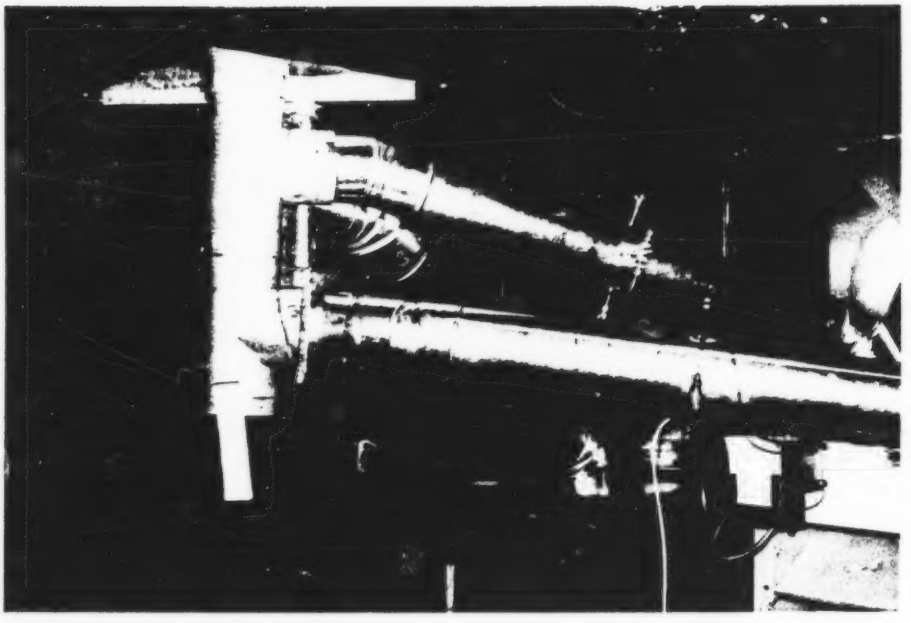


WIRING DIAGRAM

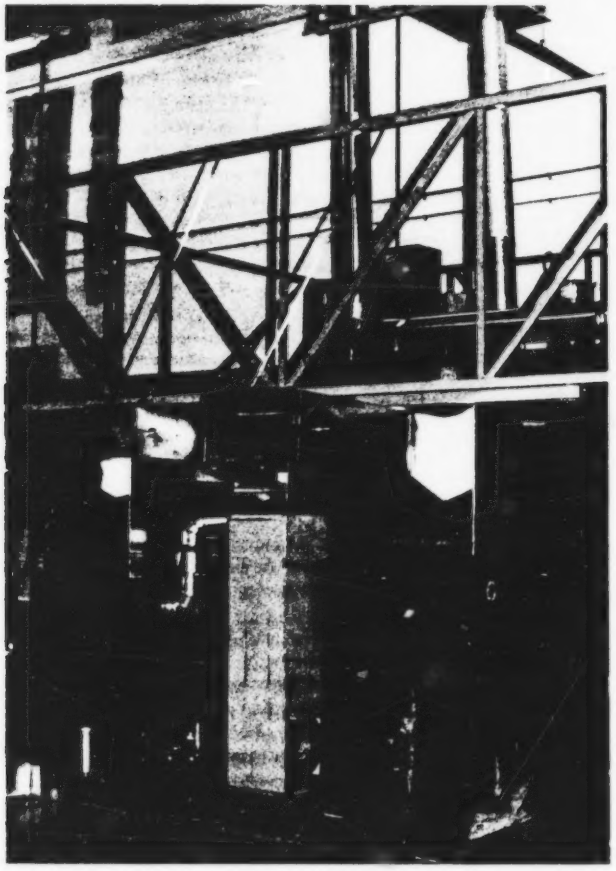
Figure 4 Appendix 3



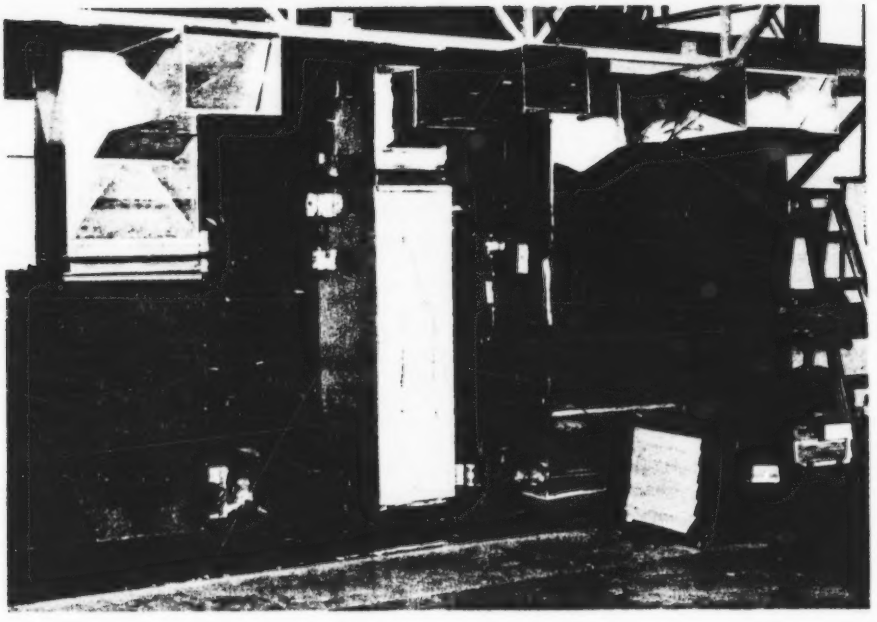
Flue Gas Analysis Equipment



Furnace Breeching Connections to B-Vent Chimneys

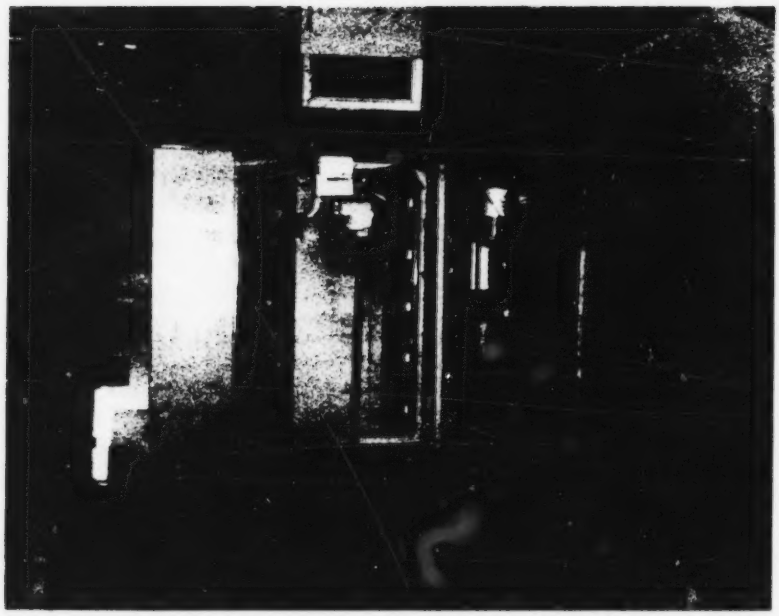


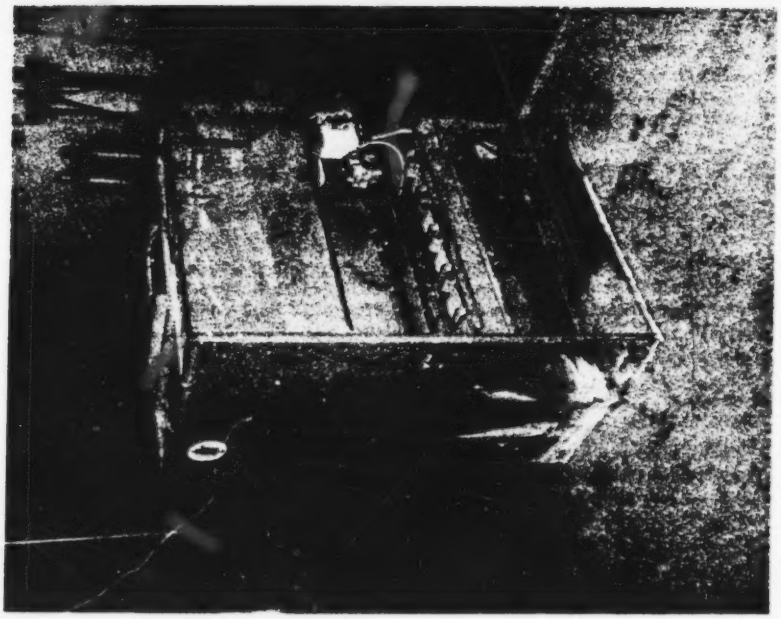
Before Retrofit



After Retrofit

Furnaces set-up in test cell at Industrial Technology Centre

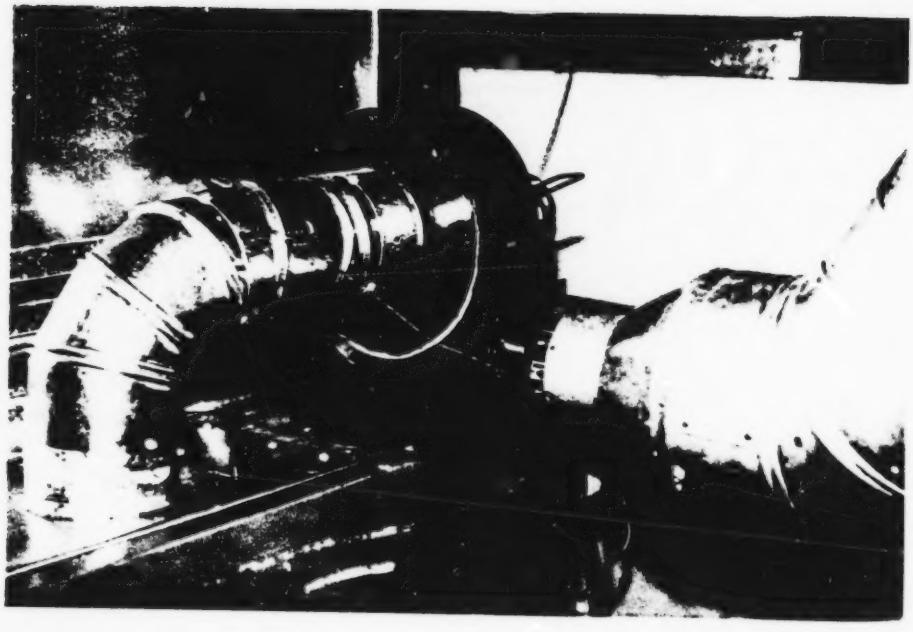


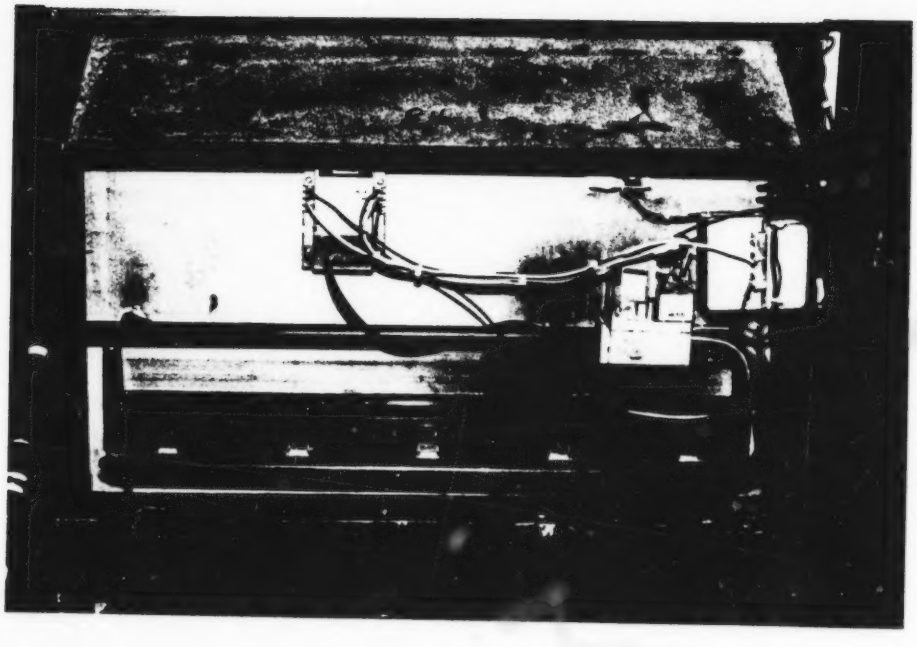


Clare (GF #1) - Before Retrofit)

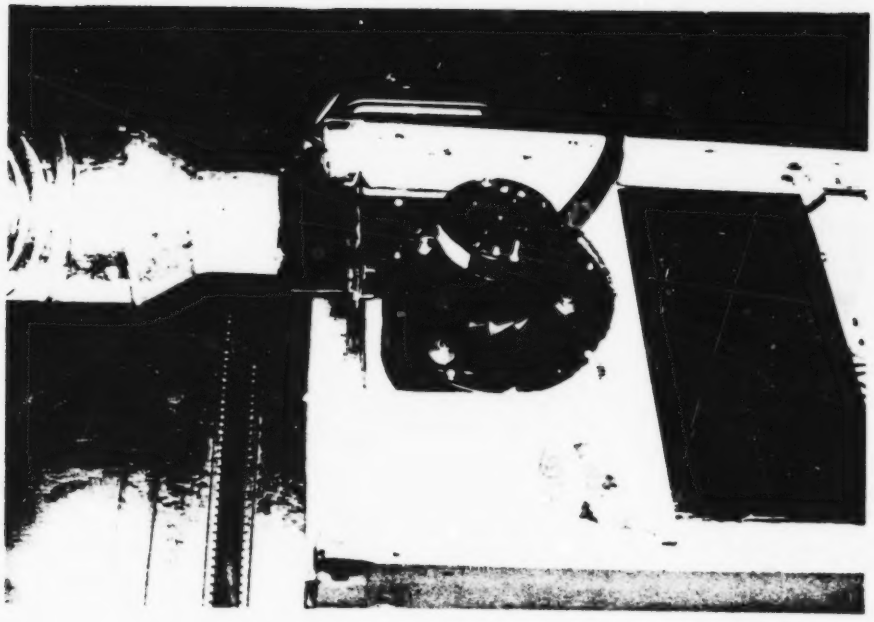
Bulloch Centurion - Before Retrofit

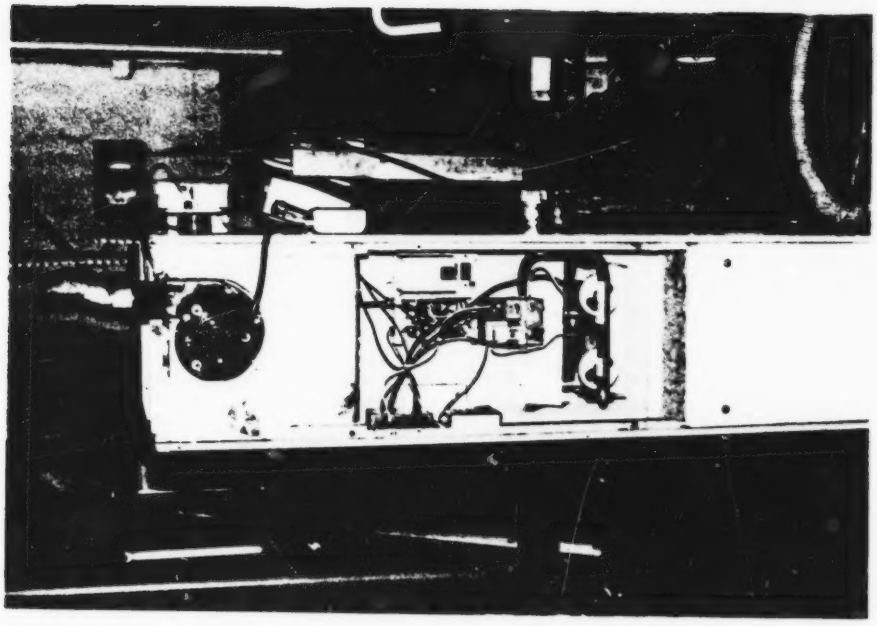
Furnasman (GF #2) - Before Retrofit



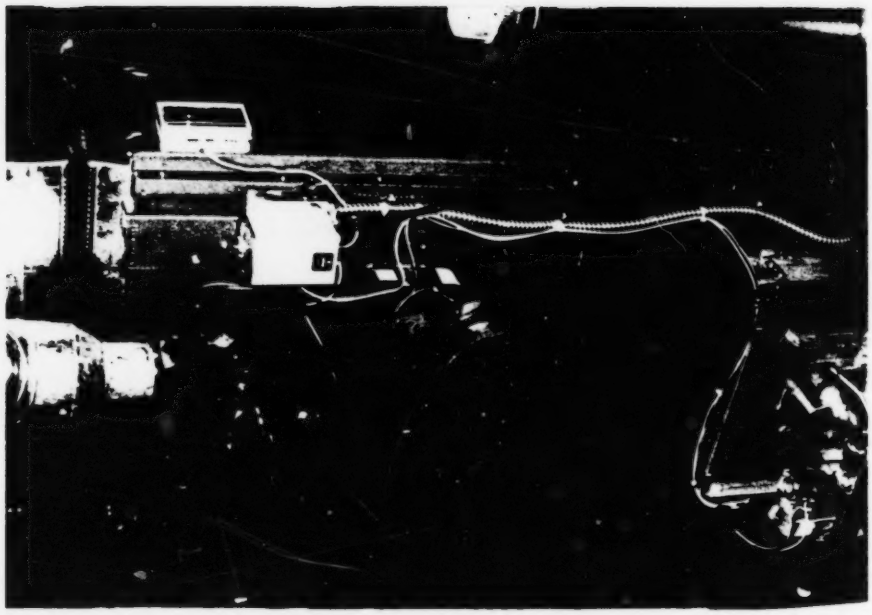


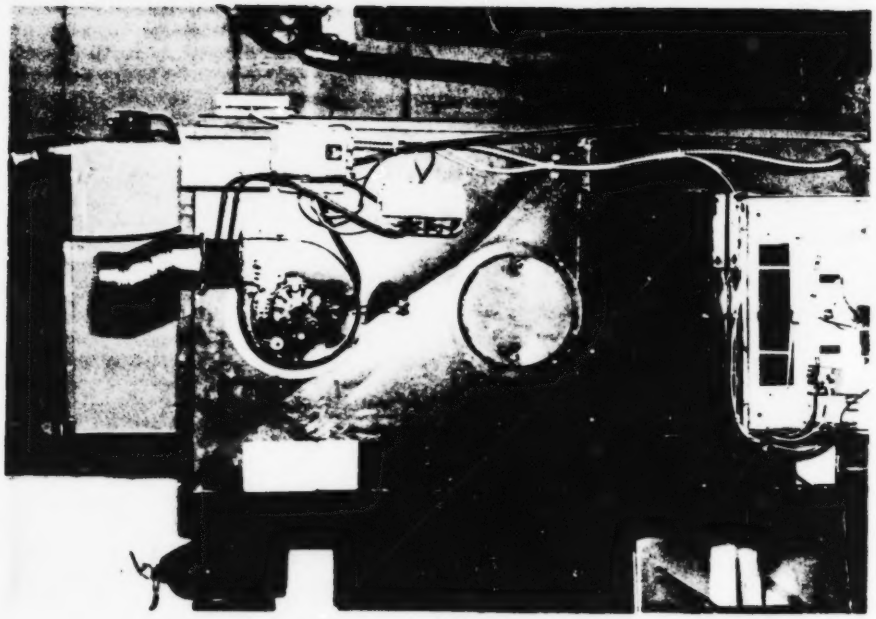
Clare (GF #1) - After Retrofit





Furnasman (GF #2) - After Retrofit





Bulloch Centurion (GF #3) - After Retrofit

Sample Calculations

1) Excess Air

Theoretical Air = Firing Rate x 9.5 m^3 air/m^3 fuel

Actual Flue Volume = A/F ratio x Firing Rate

$$\text{Excess air \%} = \left(\frac{\text{Actual Flue Vol.} - \text{Theoretical Air}}{\text{Theoretical Air}}\right)$$

Air Fuel Ratio (A/F) was determined by balancing the combusion equation.

Sample: Test #10A

Theoretical Air = 2.27 m^3/h x 9.5 m^3/m^3 = 21.6 m^3/h

Actual Flue Volume = 15.3 x 2.27 m^3/h = 34.7 m^3/h

$$\text{Excess air \%} = \left(\frac{34.7 - 21.6}{21.6}\right) \times 100\% = 61\%$$

2) Steady State Efficiency

Reference: "A Combustion Handbook for Canadian Fuels" F.D. Friedrich and A.C.S. Hayden.

From Figures 4, 5 and 6 of Set 1007 for natural gas, dry flue gas losses, hydrogen losses and CO losses were calculated as follows:

Sample: Test #10A

.1	Dry flue gas loss, from Figure 4 at 161% total air and temperature differential of 388 - 72 = 316°F	8.6%
.2	Hydrogen loss, from Figure 5 at a stack temp. of 388°F and combustion air temperature of 72°F	11.2%
.3	CO loss, from Figure 6 at 0.007% CO	0.0%
	Total Losses	19.8%

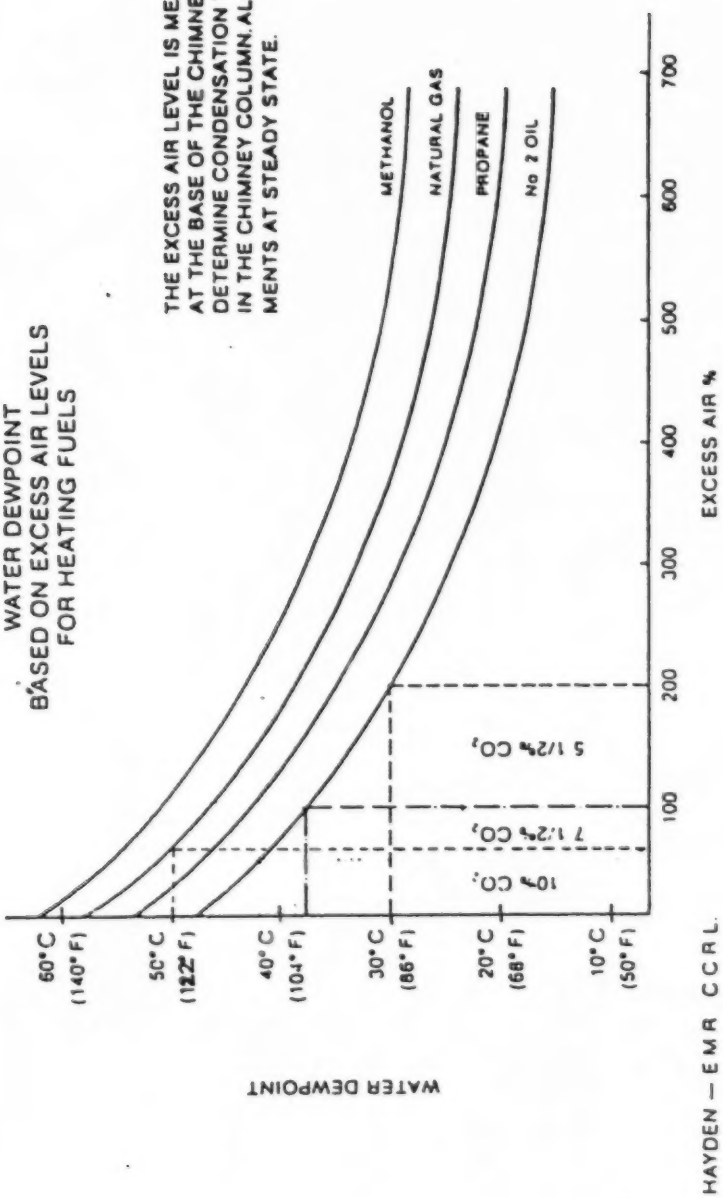
Steady State Efficiency = 100% - 19.8% = 80.2%

3) Dewpoint

The following graph, (provided by CCRL) was utilized.

Sample: Test #10A

For 61% excess air from graph dewpoint = 50°C


WATER DEWPOINT
BASED ON EXCESS AIR LEVELS
FOR HEATING FUELS
THE EXCESS AIR LEVEL IS MEASURED AT THE BASE OF THE CHIMNEY TO DETERMINE CONDENSATION TEMPERATURE IN THE CHIMNEY COLUMN. ALL MEASUREMENTS AT STEADY STATE.
METHANOL
NATURAL GAS
PROPANE
No 2 OIL
5 1/2% CO2
7 1/2% CO2
10% CO2
60°C (140°F)
50°C (122°F)
40°C (104°F)
30°C (86°F)
20°C (68°F)
10°C (50°F)
WATER DEWPOINT
100
200
300
400
500
600
700
EXCESS AIR %
HAYDEN — E M R C C R L.